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Transactions of American Society for Steel Treating

Vol. XIV November, 1928 No. 5

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NITRALLOY

DEFINITIONS

NITRIDING—*The process by which special steels can be surface hardened at a low temperature by the action of ammonia.*

NITRALLOY—*Steels of special analysis for use in the nitriding process.*

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AGATHON NITRALLOY

THE

TRANSACTIONS

OF THE

AMERICAN SOCIETY FOR STEEL TREATING

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RAY T. BAYLESS, *Editor*

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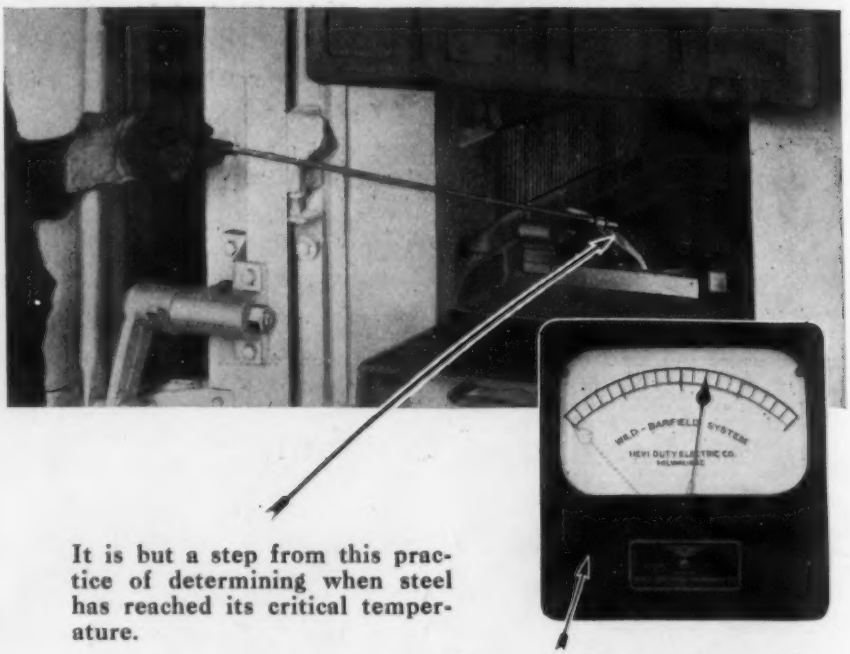
Ready To Quench?



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to this

New electro-magnetic device, an improvement, and which is exact.

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TRANSACTIONS
American Society for Steel Treating

VOL. XIV NOVEMBER, 1928 NO. 5

NEW OFFICERS NOMINATED

THE National Nominating Committee as duly elected by the chapters of the Society and in accordance with the constitution of the Society met on Monday morning, October 8, 1928, at 10:00 A. M. and nominated the following men as officers and directors of the Society:

For President .....Dr. Zay Jeffries
For Vice-President .....R. G. Guthrie
For Secretary .....W. H. Eisenman
For Director .....A. H. d'Arcambal
For Director .....F. T. Sisco

In accordance with the revisions to the Constitution of the Society as approved at the annual meeting of the Society, Wednesday, September 21, 1927, if no other candidate for officers or directors be nominated as provided in Article XI, Section 4, subdivision C, then the National Secretary shall notify the tellers, who shall certify the election of the candidates nominated. This method of election renders unnecessary the sending out of letter ballots where there are no nominations other than those presented by the regular nominating committee.

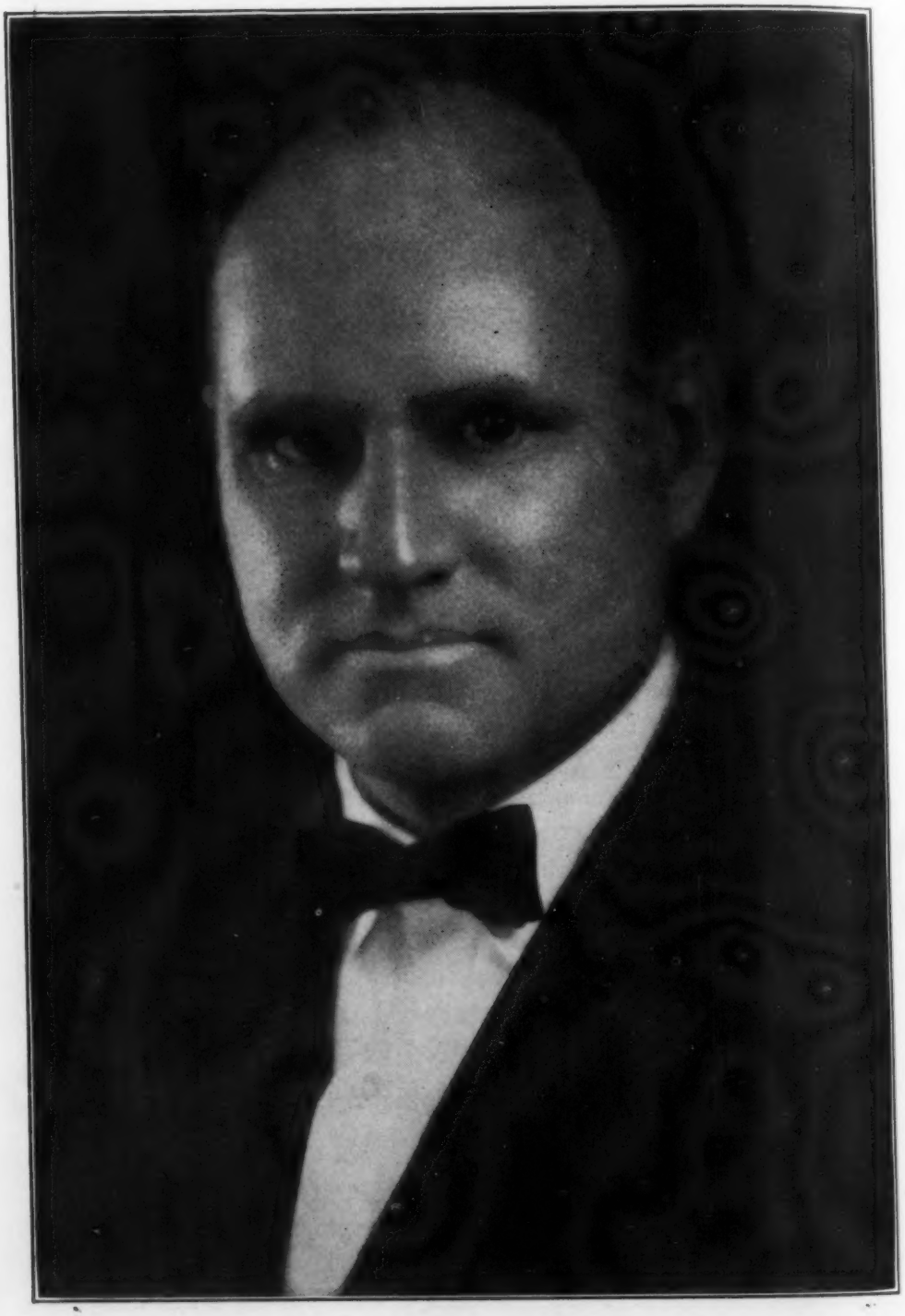
BIOGRAPHIES OF NOMINEES

Dr. Zay Jeffries

Nominated President of the Society

Zay Jeffries, consulting metallurgist of the Aluminum Company of America; consultant, Incandescent Lamp Department of the General Electric Company at Nela Park, Cleveland, Ohio, and consultant, National Tube Company, Pittsburgh, Pa., was born April 22, 1888, at Willow Lake, South Dakota.

Zay Jeffries was educated in the public and high schools of



DR. ZAY JEFFRIES
Nominee for President of the Society for the Year 1929

ROBERT G. GUTHRIE

Nominee for Vice-President of the Society for the Year 1929

WILLIAM H. EISENMAN

Nominee for Secretary of the Society for Two Years (1929-30)

ALEXANDER H. d'ARCAMBAL

Nominee for Director of the Society for Two Years (1929-30)

FRANK T. SISCO

Nominee for Director of the Society for Two Years (1929-30)

Pierre, S. D., graduating from the latter in 1906, later taking a course at the South Dakota School of Mines, Rapid City, South Dakota, graduating therefrom in 1910 with degree B. S. (Mining Engineering); in 1914 he received the additional degree of Met. E. (Metallurgical Engineer); in 1918 he received the degree, Doctor of Science (S. D.) from Harvard University.

In 1911 he accepted a position as instructor in metallurgy at Case School of Applied Science, Cleveland, Ohio, and in 1916 he was appointed assistant professor of metallurgy at the same school. While there he carried on consulting and experimental work in metallurgy for the Electric Railway Improvement Company, Cleveland Steel Tool Company, W. S. Tyler Company, the Lincoln Electric Company, National Lamp Works of General Electric Company (Cleveland Wire Division), and the Aluminum Castings Company, all of Cleveland, Ohio.

In 1917 Mr. Jeffries resigned from Case School of Applied Science, and since then he has devoted most of his time to research work for the Aluminum Company of America and the Incandescent Lamp Department of General Electric Company.

Dr. Jeffries has rendered invaluable service to the society, having been treasurer for four years and vice-president one year.

Robert G. Guthrie

Nominated Vice-President of the Society

ROBERT G. GUTHRIE, of Chicago, is chief metallurgist of the People's Gas Light and Coke Company. He served on the Board of Directors of the Society in 1925 and '26 and has also acted as Chairman of the Chicago Chapter, American Society for Steel Treating.

Mr. Guthrie specializes in high power metallography which he applies in his research work for the many industrial consumers of gas in the Chicago district. He has made many contributions to professional journals, his latest having been almost entirely in the field of metallography.

Mr. Guthrie is 38 years old. He has been engaged in mining and metallurgy of iron and steel since the beginning of his career.

William Hunt Eisenman

Renominated Secretary of the Society for Two Years

W. H. EISENMAN was born in Jamestown, Ohio, July 7, 1882,

and was graduated from Kenyon College, receiving the degree of Ph. B. He took post graduate work at Leland Stanford, Jr., University, specializing in law and sciences and received an M. A. degree for special research work in chemistry. In addition, he completed post graduate work at Morningside College and Ohio State University.

Mr. Eisenman was successively principal of a high school; instructor in chemistry, Racine College; head of chemistry department of large high school and superintendent of schools. Finally he was made secretary of the American Society for Steel Treating, which position he holds at the present time.

Alexander H. d'Arcambal
Nominated for Director for Two Years

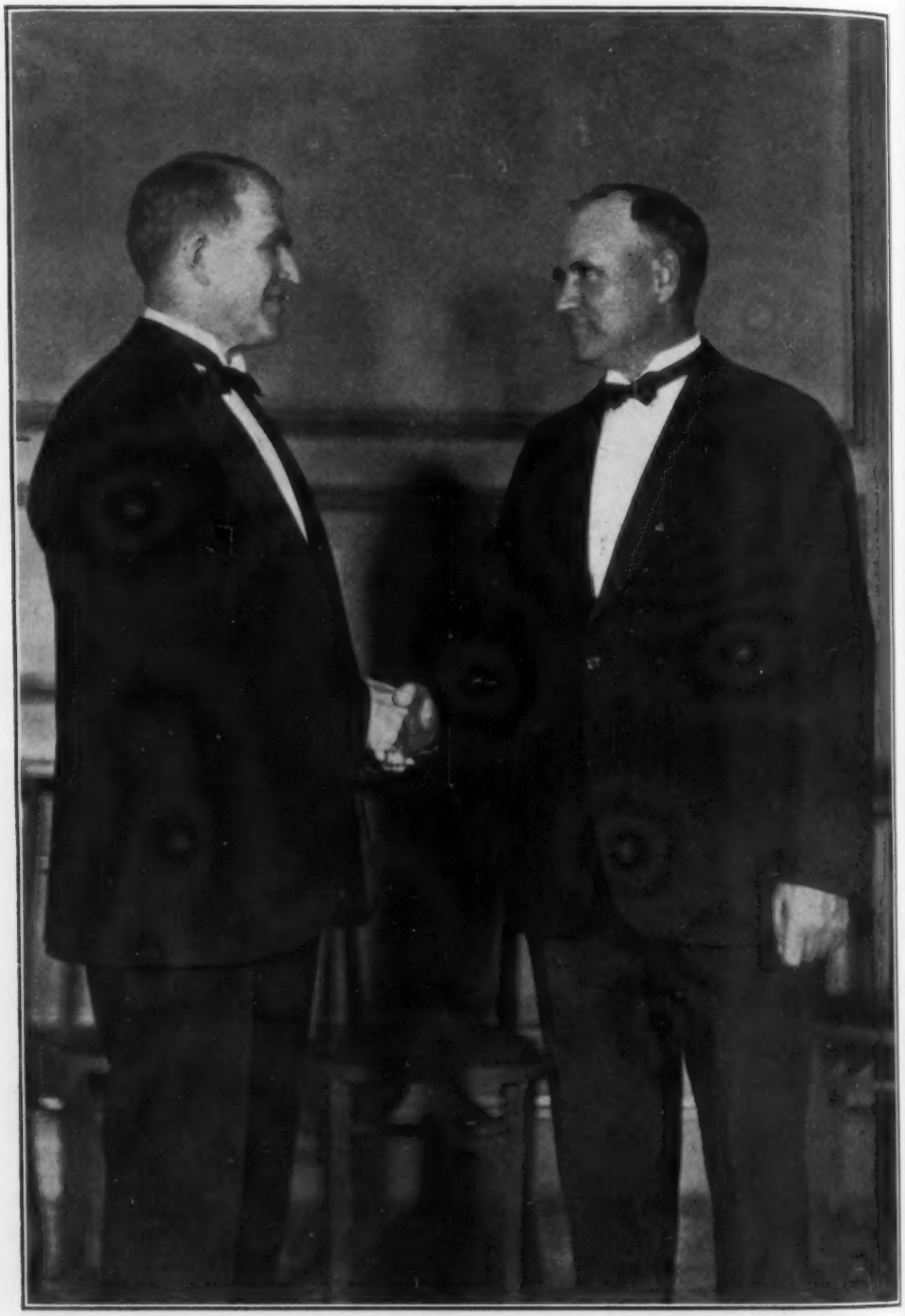
ALEXANDER H. D'ARCAMBAL was born in Kalamazoo, Mich., on January 23, 1890. He attended the Detroit Central High School and graduated from the University of Michigan with the degree of B. of Ch. E.

He has held the position of chemist with the Detroit Copper and Brass Rolling Mills, the Chalmers Motor Car Company and the Dodge Brothers Company. In 1913 he became connected with the Wright-Martin Aircraft Corporation as metallurgist. He is now consulting metallurgist with the Pratt and Whitney Company of Hartford, Conn.

Mr. d'Arcambal has held the chairmanship of the Hartford Chapter and has been active in the work of that group for several years. He is also a member of the Publication Committee and chairman of the Sub-Committee on Relation of Design to Heat Treatment.

Frank T. Sisco
Nominated for Director for Two Years

F. T. SISCO was born at Lawrence, Kansas, and received his education at the University of Illinois. During the past 12 years he has been connected with the Chicago and Northwestern Railway Company; The Illinois Steel Company; The Hess Steel Corporation; U. S. Naval Ordnance Plant, and The American Steel and Wire Company; as chemist, engineer of tests, metallurgist and superintendent of finishing departments. In 1923 Mr. Sisco accepted appointment as research metallurgist with the engineer-



F. G. HUGHES AND DR. ZAY JEFFRIES

ing division, Air Service, War Department, Wright Field, Dayton, Ohio, where he now holds the position of chief of metallurgical laboratory.

Mr. Sisco is author of two books: "Technical Analysis of Steel and Steel Works Materials" and "Manufacture of Electric Steel," and has prepared numerous papers on ferrous and nonferrous metallurgy for the technical journals and for technical societies of this country and England. Many of his articles have been published in the TRANSACTIONS of the Society.

THE CONVENTION AND EXPOSITION AS SEEN BY OTHERS

IN an eleven-page review of the Tenth Annual Convention and Exposition of the American Society for Steel Treating, held in Philadelphia, October 8 to 12, 1928, *Iron Trade Review* says in part in its October 18 issue, that—

"Marked by a technical program of unusual high merit and an exposition by pleasing diversity in the products, equipment and materials displayed, the Tenth Annual convention and show of the American Society for Steel Treating, which was held last week in Philadelphia, more than realized the hopes of its most ardent sponsors. Joining forces with the American Welding Society and the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, the steel treaters conducted their activities under the name of 'National Metal Week,' descriptive and appropriate in every sense. All records for attendance at a technical session were broken when about 600 crowded their way into the ballroom of the Benjamin Franklin hotel Wednesday to hear Dr. W. H. Hatfield deliver the annual Campbell Memorial lecture. Interest in the technical sessions continued unabated throughout the week, due perhaps to the fact that never before have so many papers of such timely value been gathered together for presentation at an annual meeting of the society. The paper announcing the development of a new tungsten carbide tool material which promises to have a direct influence on the practice of machining hard steels and nonmetallic materials, which was delivered at the Thursday morning session, is fairly typical of the important character of the data contained in many of the papers.

"The Tenth Annual National Metal exposition held in the

Philadelphia Commercial museum, a complete description of which appeared in last week's issue of *Iron Trade Review,* constituted a realistic panorama of the latest developments in equipment, materials, processes and supplies required for the making, treating, fabricating, and assembly of metal products for industry. That the exhibits attracted more than casual attention from the thousands who thronged the exposition hall was evidenced by the fact that before the show was half over, many of the articles exhibited were placarded with 'sold' signs.

"The serious side of the convention was balanced by a well rounded program of entertainment which included a grand ball on Tuesday evening, an annual banquet on Thursday evening, numerous inspection trips to industrial plants in and around Philadelphia, and a varied program for the ladies."

Speaking of the convention and exposition, *Iron Trade Review* editorially comments under the title of "Philadelphia Metal Week Successful" as follows:

"Another National Metal Week has come and gone and with its passing another scientific and industrial achievement is recorded upon the pages of modern progress. Meeting in Philadelphia last week in simultaneous conventions, the American Society for Steel Treating, the American Welding Society and Institute of Metals attracted attention from the metalworking industries not only from America but from abroad as well.

"Metallurgists and metal fabricators play major roles in providing for the needs of mankind. Our transportation systems, including travel on land, sea and air, are but one example of what has been accomplished through the study, development and treatment of metals and their alloys. As time passes, it might be supposed that the fields of discovery are narrowing and that our greatest strides already have been made.

"A review of the activities of last week, however, indicates that perhaps our greatest achievements lie ahead. New cutting materials are being developed, improved heat treatments are providing superior physical properties in tool steels and structural materials and new methods of joining metals together are effecting substantial economies. A visitor at any session conducted in Philadelphia last week could not but wonder as to what startling developments will result from research during the next 12 months.

"Perhaps a more tangible evidence of progress was to be

gained from the National Metal Exposition, where the latest furnaces, metallurgical equipment, testing apparatus, steels and alloys, welding machinery and welded products were displayed for inspection. That industry appreciates the importance of keeping abreast of progress was indicated by the fact that before the exposition had closed much of the equipment was tagged as 'sold.' The 1928 National Metal Week must be pronounced unusually successful."

Iron Age

In a twelve-page report of the exposition and convention of the Society, *Iron Age* of October 18, 1928, comments as follows:

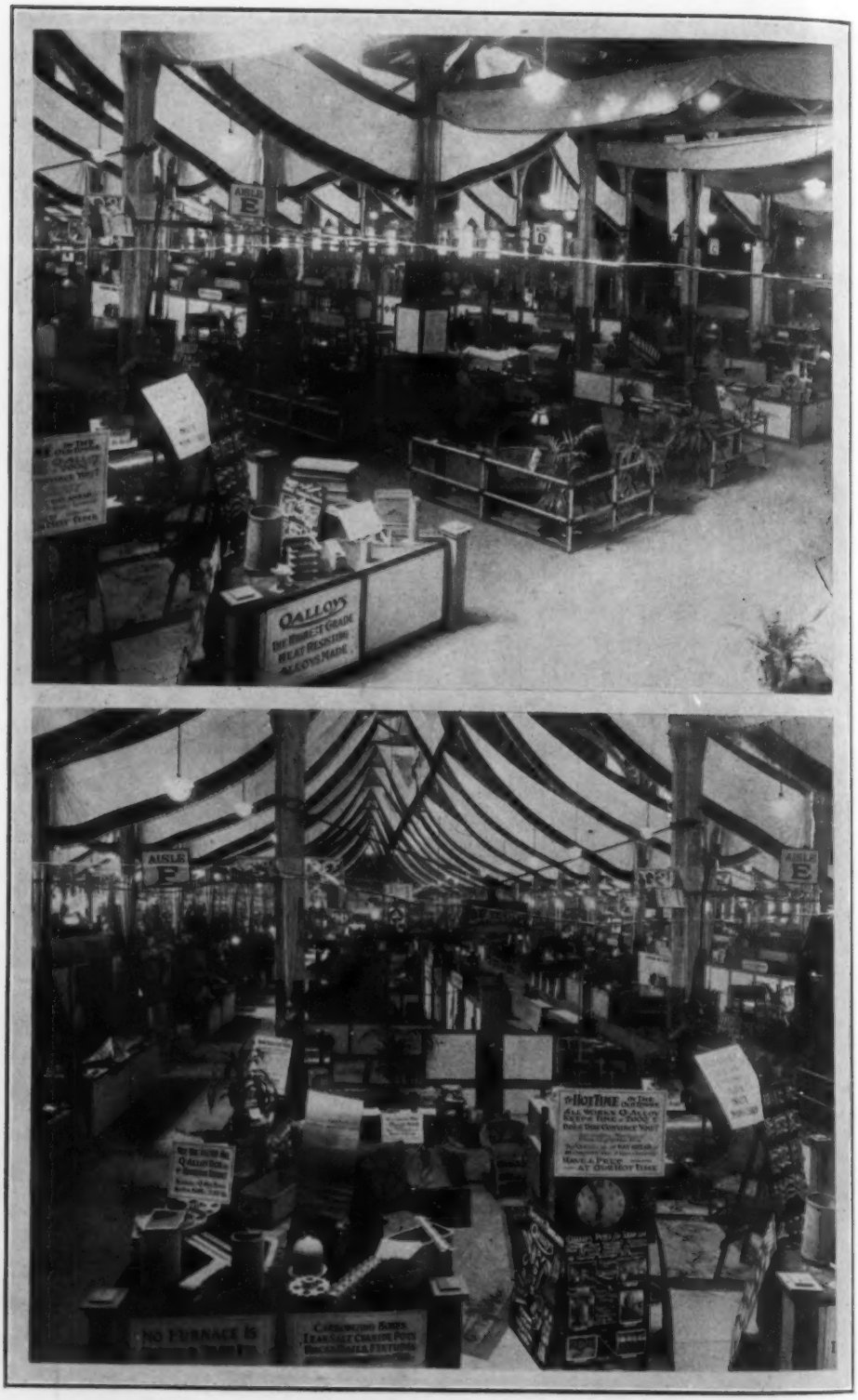
"Meeting in the city and hall where it held its second annual convention and exhibition in 1920, the American Society for Steel Treating last week, Oct. 8 to 12, celebrated its tenth annual gathering at Philadelphia. Those who were present at both conventions could not fail to be impressed with the remarkable strides which have been made in heat treatment both technically and in equipment as reflected in the exhibits.

"Augmented by simultaneous conventions of the Institute of Metals and of the American Welding Society, National Metal Week again brought together groups of men whose interests interlace in varying degrees in the fields of pure science, practical metallurgy and work-a-day shop procedure.

"A feature of the week was the Campbell memorial lecture by Dr. W. H. Hatfield, noted British metallurgist, which was listened to by about 550, a record for such gatherings.

"The National Metal Exposition, while not so large as those of 1927 in Detroit and of 1926 in Chicago, was a marked success. Its compactness and attractiveness were commented upon, and exhibitors generally were optimistic as to the results and concede it one of the best in years.

"Offering nearly 40 papers at 10 sessions the technical program was up to a high standard. Only a few of the important ones can be reviewed here. They all illustrated the progress being made in various fields of heat treatment."



VIEWS OF THE EXPOSITION

NATIONAL METAL WEEK AND THE TENTH ANNUAL CONVENTION AND EXPOSITION OF THE AMERICAN SOCIETY FOR STEEL TREATING, PHILADELPHIA, OCTOBER 8 TO 12, 1928

HIGHLY successful was the tenth annual convention and exposition of the American Society for Steel Treating held in the historical old city of Philadelphia the week of October 8, 1928. Meeting simultaneously with the American Society for Steel Treating were two other technical societies, the American Welding Society and the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers with a combined registration in excess of 3000 members who participated in the program of National Metal Week.

The registration of members of the individual societies included 300 members of the American Welding Society, 125 members of the Institute of Metals, and 2714 members of the American Society for Steel Treating, which is 56 per cent of the total membership of the society.

The exposition and convention of the three societies was indeed a successful affair. The National Metal Exposition located in the Commercial Museum, while not as large in the point of floor space as the exposition held in Detroit last year was a most complete success. The diversity of products displayed and the interesting and novel exhibits showing the latest developments in steels, testing apparatus, heat treating machines, welding equipment and countless other accessories depicted the advances which have been made during the past twelve months and made this year's show an outstanding success.

Again this year, as with last year, the American Welding Society combined their welding exhibit with that of the National Metal Exposition, augmenting both their own exposition and that of the Steel Show. We are pleased to announce that the American Welding Society and the Institute of Metals will again take part in the activities of National Metal Week, which will be held in Cleveland the week of September 9, 1929.

Each of the three co-operating societies held technical sessions throughout the week of October 8. The American Welding Society held their meetings at their headquarters' hotel, the Bellevue Stratford, and also at the Commercial Museum, while the

Institute of Metals and the American Society for Steel Treating held their technical sessions at their headquarters' hotel, the Benjamin Franklin, and also at the Commercial Museum. There were some 65 technical papers in all read before these three societies throughout the week, 41 of which were on the program of the American Society for Steel Treating.

For the benefit of those members of the society who were unable to be in Philadelphia during National Metal Week this year we are publishing in this issue of TRANSACTIONS a review of the activities of the program for the week of October 8, 1928, which constituted the convention and exposition of the three societies. The events are arranged in chronological order.

The exposition was open each day at the Commercial Museum from 12:00 noon to 10:00 P. M., with the exception of Tuesday and Thursday, on which days the exposition closed at 6:00 P. M.

All morning sessions of the American Society for Steel Treating were held in the Ball Room of the Benjamin Franklin hotel, while all afternoon sessions were held at the Commercial Museum.

The American Welding Society held their morning technical sessions at the Bellevue Stratford and their afternoon sessions at the Commercial Museum.

The Institute of Metals held their morning sessions at the Benjamin Franklin Hotel and one afternoon session was held jointly with the American Society for Steel Treating at the Commercial Museum.

The technical sessions were better attended this year than ever before with a usual attendance of 400 to 500 for each session. Again, an accurately arranged time schedule was used in conducting the technical session and this, as in past years, was found to work out admirably and met with unanimous approval of all who attended the sessions.

For the fourth consecutive year *Daily Metal Trade* published a *Steel Treaters' Daily* which gave a comprehensive review of the activities during National Metal Week. Four editions were published and distributed at the convention. Copies were likewise mailed to all members of the Society.

MONDAY, OCTOBER 8

Monday, October 8, the first technical session of the Tenth Annual Convention of the American Society for Steel Treating

convened at 10:00 A. M. This meeting was held in the ballroom of the Benjamin Franklin Hotel and was called to order by Robert M. Bird, past president of the Society and member of the committee representing the Board of Directors in making arrangements for the 1928 Convention, who introduced Henry B. Allen, vice-chairman of the Philadelphia Chapter. On behalf of the Philadelphia Chapter, Mr. Allen extended greetings and welcome to the visiting members of the American Society for Steel Treating. Following this introduction, Chairman Bird immediately proceeded with the technical program consisting of a schedule of four papers, which were as follows:

10:00—10:30 A. M.—*An Investigation of the Physical Properties of Certain Chromium-Aluminum Steels*—Frank B. Lounsberry and Walter R. Breeler, Atlas Steel Corporation, Dunkirk, N. Y.

10:30—11:00 A. M.—*Chromium-Copper Steels as Possible Corrosion Resisting Ferrous Alloys*—B. D. Saklatwalla and Albert W. Demmler, Vanadium Corporation of America, Bridgeville, Pa.

11:00—11:30 A. M.—*A New Development in Corrosion-Resisting Steel*—Frank R. Palmer, Carpenter Steel Co., Reading, Pa.

11:30—12:00 A. M.—*Stainless Iron and its Application to the Manufacture and Transportation of Nitric Acid*—Walter M. Mitchell, Central Alloy Steel Corp., Massillon, Ohio.

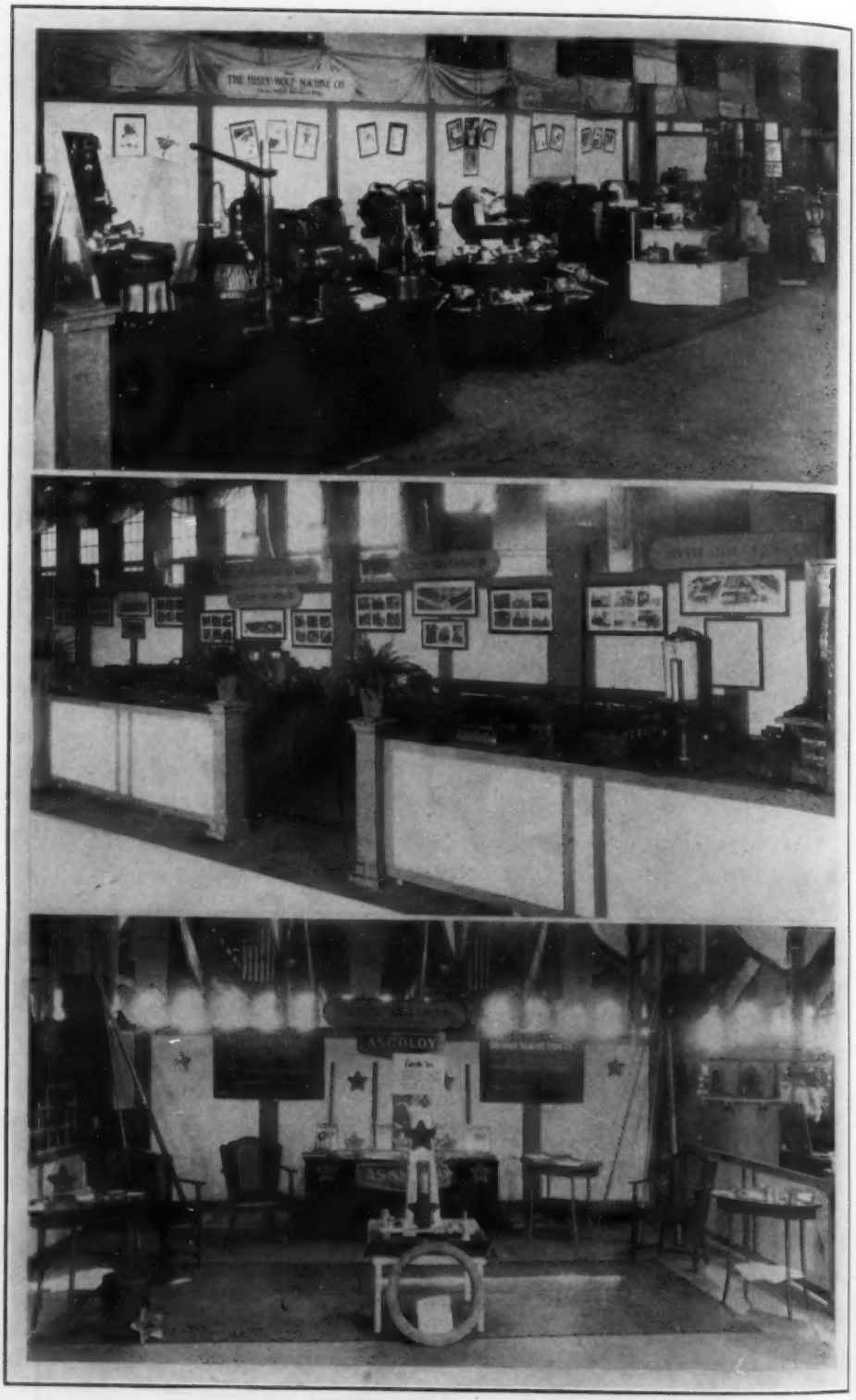
Each of these papers was presented by its respective author and in the case of the first two papers the junior authors made the presentation. The papers were held closely to the time limit as scheduled, but much interesting and valuable discussion was presented in each case.

The second technical session was held in the assembly room of the Commercial Museum and was called to order by Dr. A. E. White at 2:30 P. M., Dr. V. O. Homerberg serving as vice-chairman of the session. Four papers were scheduled for this meeting and were presented in the following order.

2:30— 3:00 P. M—.*Surface Hardening of Special Steels with Ammonia Gas Under Pressure*—Raymond H. Hobrock, Engineering Experiment Station, Purdue University, Lafayette, Ind.

3:00— 3:30 P. M.—*Methods of Approximating Certain Physical Characteristics of Nitrided Steel Cases*—G. M. Eaton, Molybdenum Corp. of America, Pittsburgh.

3:30— 4:00 P. M.—*Depth and Character of Case Induced by Mixtures of Ferro-Alloys with Carburizing Compounds*—E. G. Mahin, University of Notre Dame, Notre Dame, Ind., and R. C. Spencer, Caterpillar Tractor Co., Moline, Ill.



VIEWS OF THE EXPOSITION

4:00— 4:30 P. M.—*Solubility of Carbon in Normal and Abnormal Steels*—Oscar E. Harder, University of Minnesota, Minneapolis, Minn., and Willard S. Johnson, American Rolling Mill Co., Middletown, Ohio.

As in the case of the morning session, much valuable written and oral discussion was presented. All of this discussion will appear in the TRANSACTIONS at the time when the respective papers are published.

TUESDAY, OCTOBER 9

The Tuesday morning session of the Convention was called to order at 10:00 A. M., by Dr. John A. Mathews, chairman, who was assisted by M. A. Grossmann, vice-chairman. Four interesting papers were presented at this session which dealt largely with the making of steel. As in the case of the Monday technical meeting this session was well attended and considerable worth-while discussion was presented both in written and oral form. Dr. W. H. Hatfield favored this session with an interesting and valuable discussion. All of this discussion will appear later in TRANSACTIONS. The papers presented are as follows:

10:00—10:30 A. M.—*A Melting Record of Three Acid Open-Hearth Heats*—W. E. Griffiths, Union Carbide and Carbon Research Laboratories, Inc., Long Island City, and C. E. Meissner, Chrome Steel Works, Carteret, N. J.

10:30—11:00 A. M.—*The Equation of the Carbon-Time Curve in Basic Open-Hearth Refining and Prediction of Carbon Drop*—Alexander L. Feild, Union Carbide and Carbon Research Laboratories, Inc., New York City.

11:00—11:30 A. M.—*Manufacture of Acid Open-Hearth Steel for Forging Ingots*—H. P. Rassbach, Midvale Company, Nicetown, Philadelphia.

11:30—12:00 A. M.—*Deoxidation of Steel with Silicon*—Dr. C. H. Herty, Jr., and G. R. Fitterer, United States Bureau of Mines, Pittsburgh.

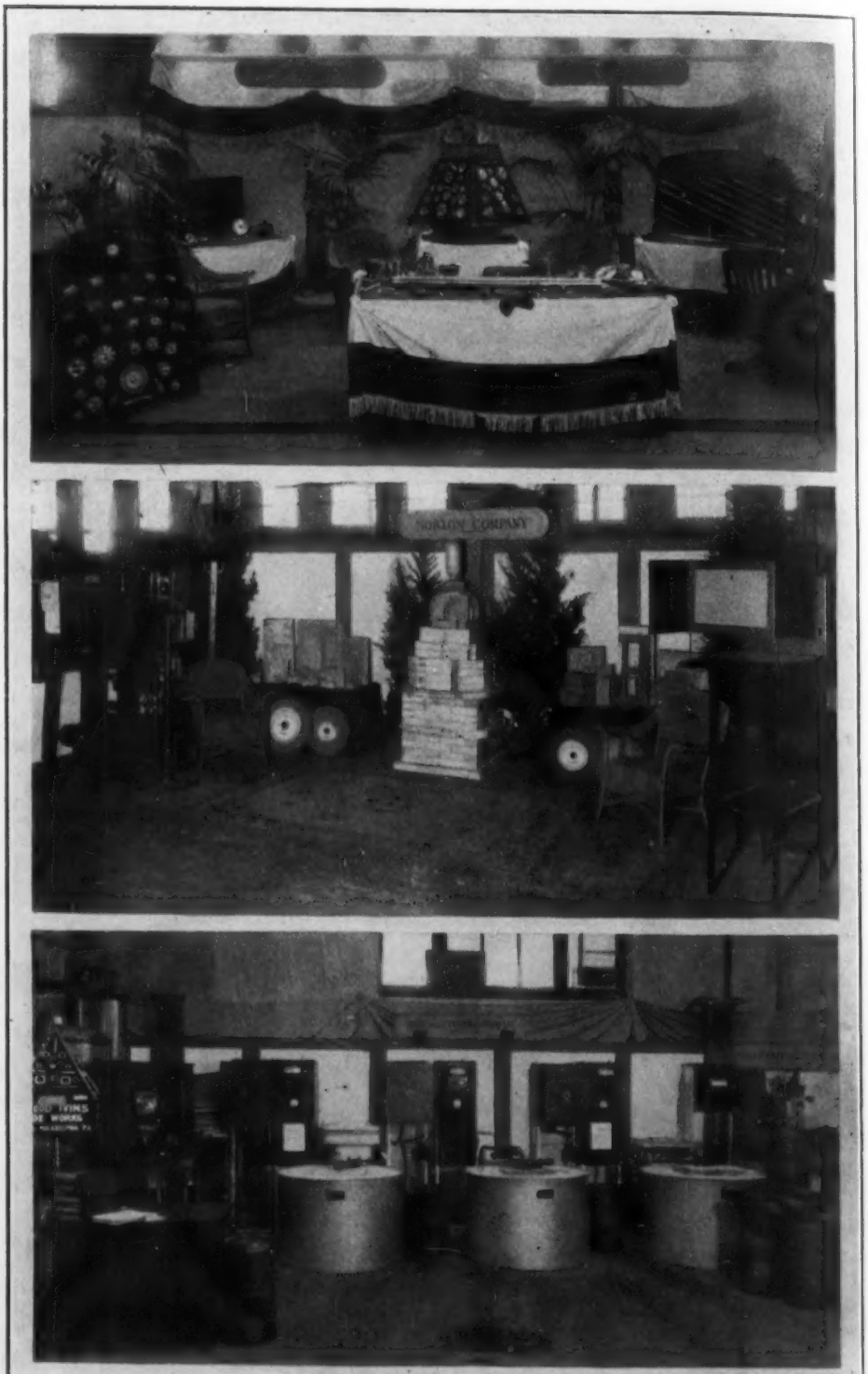
The afternoon session was called to order at 2:30 o'clock by Chairman T. D. Lynch, assisted by Edgard C. Bain as vice-chairman. Four papers were scheduled for presentation at this meeting.

2:30— 3:00 P. M.—*Graphitization in the Presence of Nickel*—H. A. Schwartz, National Malleable and Steel Castings Co., Cleveland.

3:00— 3:30 P. M.—*Influence of Nickel on Combined Carbon in Gray Iron*—J. R. Houston, The Harnischfeger Corp., Milwaukee.

3:30— 4:00 P. M.—*Some Characteristics of Pearlite in Eutectoid Rail Steels*—O. V. Greene, Reading Company, Reading, Pa.

4:00— 4:30 P. M.—*Cutting Qualities of an Alloy Steel as Influenced by its Heat Treatment*—O. W. Boston, University of Michigan, Ann Arbor, Mich., and M. N. Landis, Landis and Landis, Chicago.



VIEWS OF THE EXPOSITION

In the absence of the author of the first paper, Dr. Paul D. Merica presented the paper and very ably assisted in the discussion which followed. The following three papers were each presented by their respective authors. The interesting discussion which followed each paper will be published later in TRANSACTIONS.

GRAND BALL

One of the interesting annual functions of the Society is the informal dancing party which has become a social event which is looked forward to by many members. This year the party was held in the ballroom of the Benjamin Franklin Hotel. A large number of members and guests were in attendance. The ballroom was decorated to depict a Dutch village and this combined with the very excellent orchestra made for a most entertaining evening for everyone.

WEDNESDAY, OCTOBER 10

As has been the custom for the past few years the Annual Meeting of the Society was held on Wednesday morning. This meeting was called to order by President Hughes at 9:30 A. M. and consisted of a general business meeting wherein the president presented his annual address, the secretary his annual report and the treasurer his report upon the finances of the Society. The three reports follow in their correct order.

THE PRESIDENT'S ANNUAL ADDRESS

FREDERICK G. HUGHES, *President, 1928*

AT this, the first opportunity I have had of addressing you, I take pleasure in presenting a report of the activities of your society for the past year.

One of the defects of our organization lies in the fact that the first formal opportunity enjoyed by the one who has been your President for ten months to address the membership as a whole should occur so late in his term of office.

President Bird at a great expense of time and money endeavored to overcome this difficulty in some measure by visiting every chapter during his term of office and prior to the annual convention. Your society has now grown so large, its chapters already spreading from coast to coast, that we cannot expect in the future that the man whom you may select as your President can duplicate President Bird's self-sacrifice, and, therefore, today, I intend, after the report of the nominating committee has been made, to ask the nominees, if they be present, to appear before you and each say a few words so that you may the better know those to whom you propose to entrust the fortunes of your society for the coming year.

As you may gather from the foregoing, it has been impossible for your President to visit the various chapters during the past year, and it has fallen upon the able shoulders of our Secretary and his office in Cleveland to carry on the activities of the National Society to maintain contact with the various chapters and groups and to promote their advancement and increase. It is my belief that the years to come will find this the usual and most satisfactory method of conducting the general society affairs.

Since the last annual meeting, held at Detroit, the change in the Constitution and By-Laws, proposed at that meeting, has been ratified. It has seemed wise to your Board to suggest a slight additional change which, if ratified, will permit the placing our membership dues upon a fiscal basis similar to other engineering societies. This, we believe, will be a step in the direction of stabilization of membership and will enable our business officers to more accurately budget expenses against income, and we, therefore, trust that the amendments necessary to accomplish this will meet with your approval.

During the past year, upon approval from the Board, two groups, Southern Tier and Montreal, have been advanced to full chapter standing. The Secretary's report will show you that the various chapters and groups of the society have maintained a healthy growth in membership during the year. From reports received, it appears that never before have there been more profitable chapter meetings held throughout the country by the chapters than has been the case during the year just past. The general quality of papers presented and character of meetings held by each chapter, we believe, will compare most favorably with those of any other similar organization. We wish to emphasize that the growth and real value of the society to its membership and to industry at large most largely depends upon the character and quality of the chapter meetings. It is in these meetings that the general membership gains information of far greater value than is possible to get even at an annual meeting such as we are now holding, and we must most strongly urge the chapter executives to give even greater thought to the preparation of their programs in the years to come.

From the Treasurer's report, you will gather that the finances of your organization are sound, that additional sums have been invested in selected securities as an endowment and back-log against the future.

While the minutes of the various meetings of your National Board of Directors are, in accordance with custom, printed in the TRANSACTIONS, I am quite sure that the average member of the society who has not been a member of the Board little realizes the amount of time and hard work given to the advancement of their interest by the unselfish collaboration of the members of the National Board. Exigencies have called for an unusual number of Board meetings during the past year. In every case, each meeting of the Board has taken an entire day from early morning to late at night. The last meeting of the Board, held at Cleveland, prior to your annual meeting, consumed two solid days. Considering the time travelling to and from such Board meetings and realizing that each meeting means from three to four days away from his own business for each director and officer of your society you can well appreciate that membership on your National Board of Directors is no sinecure.

I know of no group of business executives who more assiduously watch the interest of their business than have the directors of your society in the four years of my service therewith. I therefore wish to take this opportunity of thanking each officer and member of the National Board for his unselfish service to the society.

The outcome of the Detroit Exposition of last year was satisfactory from every viewpoint. We confidently expect that the Philadelphia Exposition, now in progress, under a somewhat reduced scale as compared to Detroit and Chicago, will be relatively as satisfactory. We bespeak the continued co-operation of our exhibitor friends in these unique expositions and trust that the exposition of 1929, in Cleveland, will continue our record of successful shows.

I desire, at this time, to remind you of the obligation our society owes to the exhibitors at the National Metal Show and to remind our membership that they can evince their appreciation of this exhibitor co-operation in a most practical and profitable way through the buying and specification of our exhibitors' goods. As long as the membership and those allied with the co-operating societies make it profitable for exhibitors to show their wares at our expositions, so long will these expositions be a success and the society as a whole benefit thereby. Without these expositions, the educational activities of your society, of necessity, would be materially curtailed.

The activities of your National Committees have been evidenced to you throughout the year. The Publication Committee, under the able chairmanship of Professor H. M. Boylston, and the Editorial Staff, under the direction of Mr. Ray Bayless, have provided TRANSACTIONS without parallel in interest and value. We wish to express our appreciation to Mr. W. B. Coleman who has been successful in securing a collection of marvelously interesting papers for this meeting.

It seems to me that with the issuance of the new HANDBOOK, on which Mr. Edward Donnellan of the Cleveland office has expended a great amount of hard and satisfactory work, that the labors of the Recommended Practice Committee for many years past have come to full fruition, and that every member of the society who has had any part in the framing of these Recommended Practices now appearing in bound form should feel proud of the accomplishment.

It is impossible to individually thank each member of the National Committees and their sub-committees for his work in the interest of the society during the past year. The self-sacrificing, hard work of these committee members deserves the thanks of every member of the society. Membership on these National Committees is hard work for men already busy. The same may be said of the activities of the chapter executives and executive committees who put in many hours of hard planning and work for the growth of the society and the furtherance of its objects.

I take this opportunity on behalf of the National Board of expressing its appreciation and thanks to all of these men and to ask that each member of the society do everything in his power to make the burden of his executives easier by his willing cooperation in whatever he may be called upon to do.

No address of the President could possibly be complete without reference to the work of the Central office of the Society at Cleveland and that most efficient organizer, Mr. William H. Eisenman, who, for the past ten years, has occupied the position of National Secretary.

In addition to Messrs. Donnellan and Bayless, Messrs. Kenneth Briggs and Ohlson, and their assistants, have each rendered exceedingly valuable service to the society in the past year. While the National Metal Show in Philadelphia has been organized and directed this year again by the National Office, similarly as in Detroit, I wish to thank members of the Philadelphia Chapter who by their cooperation have so greatly lessened the burdens of the National Office in connection with the Philadelphia Show.

The American Society for Steel Treating is built upon a very high ideal of service. It has grown because of its ability to give help and assistance. It has grown because it has uniquely filled a great need in industry, and by its bringing together the scientist and the practical man for the interchange of ideas and helpfulness, it has advanced the interests of both.

This society from the beginning has been unique in its effort to combine the interests of the practical heat treater and the metallographist. The early founders had mostly the practical viewpoint. That viewpoint, in my opinion, should still dominate our activities. Because the practical man is seldom a writer of papers, we may not credit him with as great a thirst for information as he really possesses. The metallographist, on the contrary, may be a prolific writer, but words themselves will not improve the cutting qualities of a high speed tool nor strengthen a bridge girder.

If the American Society for Steel Treating through its efforts can translate the science of metal treating into practically improved tools, stronger and lighter forgings or castings wrought into new shapes of increased utility to better serve the needs of the world, then and only then will the American Society for Steel Treating have begun to justify its existence.

Therefore, as you serve our society and as the American Society for Steel Treating serves society in general so only shall we truly grow.

ANNUAL REPORT OF THE SECRETARY

WILLIAM HUNT EISENMAN, *Secretary*

HONORARY MEMBERS

At the annual banquet at Detroit last year Charles F. Kettering and W. R. Whitney accepted election and certificates to Honorary Membership in the American Society for Steel Treating. Both were present in person to receive their certificates.

It is with deep regret that the Society records the death of one of its Founder Members, Arthur G. Henry, which occurred in Chicago on Wednesday, October 5, 1927.

Mr. Henry was probably the best known member of the society, having been one of a small group of men interested in forming the Chicago section of the Steel Treating Research Society, and later taking an active part in the formation of the American Steel Treater's Society in serving as the first

secretary of the Chicago Chapter as well as the first secretary of the national organization which was formed with the Chicago Chapter as a nucleus.

Henry Marion Howe Medal

The Henry Marion Howe Medal was awarded for the fifth time at the annual banquet held at Detroit last year, the 1927 recipient being Wesley P. Sykes. Mr. Sykes' paper, entitled "The Iron-Molybdenum System," had been judged the paper of highest merit published in the Transactions during the twelve months from August, 1926, to August, 1927.

Edward De Mille Campbell Memorial Lecture

The first Campbell Memorial Lecture, entitled "The Corrosion of Metals," was presented by Dr. Minot Guertler, of Germany, at Chicago in 1926. Dr. Zay Jeffries delivered the second Campbell Lecture at Detroit last year. Its title was "A Contribution to the Theory of Hardening and the Constitution of Steel."

Membership

The American Society for Steel Treating on August 31 had a membership of 4,844. Of this number 4,175 or 86.3 per cent were of member classification; 444 or 9.18 per cent of sustaining classification; 214 or 4.4 per cent of junior classification; 9 or 0.18 honorary members and two founder members. This is 4.1 per cent increase over the preceding year. Curve No. 4 and Table I shows the increase in total membership since 1920. Curves Nos. 2, 3 and 4 show the line of progress in the acquisition of members, sustaining and junior members from 1920 to date.

Table I
A. S. S. T. Membership 1920-1928

	Members	Associate	Sustaining	Junior	Honorary	Founder	Total Membership	Increase	Per Cent Increase
1920	1349	302	50	21	2	0	1724	...	....
1921	1742	341	56	25	4	0	2168	444	25.7
1922	1798	375	86	48	6	0	2313	145	6.7
1923	2048	400	191	99	6	2	2746	433	18.7
1924	2224	476	209	109	6	2	3026	280	10.2
1925	2452	500	243	160	6	2	3363	337	11.1
1926	2916	580	303	190	8	3	4000	637	18.9
1927	3436	608	382	217	11	3	4653	653	16.3
1928	4175	...	444	214	9	2	4844	191	4.1

Meetings of Board of Directors

The Board of Directors held four meetings during the past year as follows:

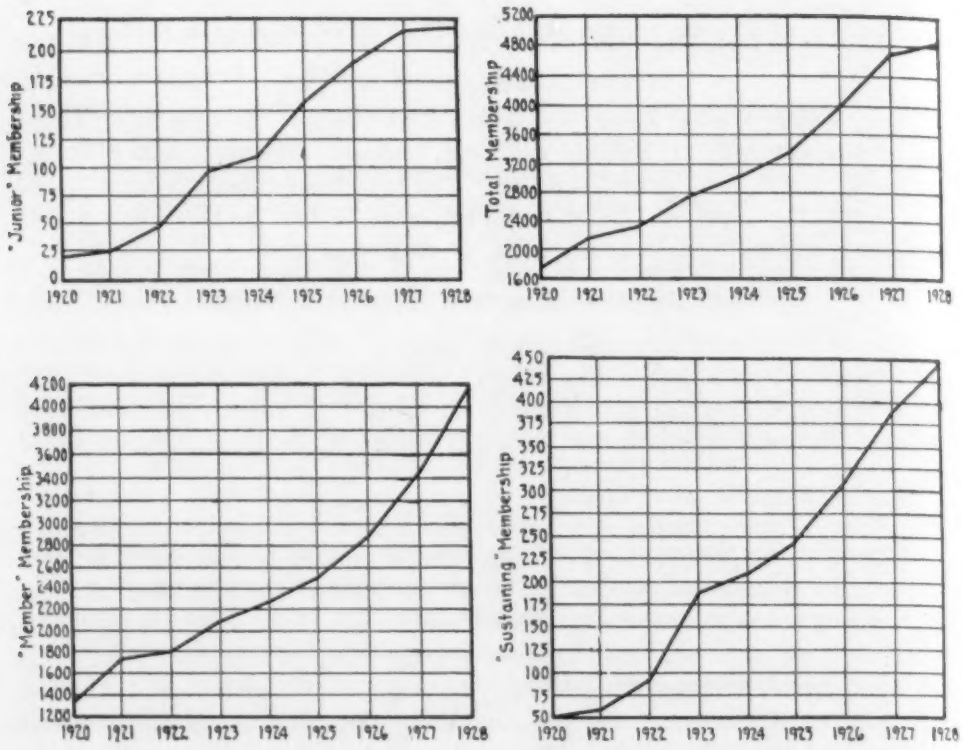
Detroit, Sunday, September 18, 1927.

Cleveland, Saturday, December 10, 1927.

Montreal, Wednesday, February 15, 1928.

Cleveland, Monday and Tuesday, July 9 and 10, 1928.

The minutes of these meetings have according to custom been published in the Transactions of the Society.



Curves Showing the Increase in Membership of the Society from 1920 to the Present Time.

Semi-Annual Meeting

The society held its Semi-Annual Meeting in Montreal, February 16 and 17. Fifteen technical papers were presented, which combined with plant inspection and the winter sports, provided a very successful meeting.

The Montreal Chapter gave very valuable assistance and co-operation in making splendid arrangements for the meeting.

Chapters and Groups

The past year has been a very successful one for the chapters. All continue in very good financial condition with splendid attendance at their meetings and with excellent programs.

The president's bell, awarded by the president each year to the chapter which in his estimation has been outstanding in accomplishments and achievements, has during the past year been in the possession of the Golden Gate Chapter.

The total assets of the chapters at the close of the fiscal year June 1, 1928, was $24,682.43.

During the past year two groups of the American Society for Steel Treating have been promoted from group to chapter rating. These two are Montreal and Southern Tier.

Educational Activities

During the past year a number of the chapters have again carried on educational work either under their own auspices or in co-operation with educational institutions located in their immediate vicinity. The results accomplished have been most desirable and encouraging, and the chapters contemplate similar activities during the coming year.

The American Society for Steel Treating in co-operation with Purdue University secured the services of a steel expert, John F. Keller, who for a period of six months conducted two groups in engineering extension work. The first group consisted of Canton-Massillon, Columbus, Dayton, Erie and Youngstown, with a total enrollment of 355.

The second group consisted of Chicago, Milwaukee, Rockford, South Chicago and Tri-City, with a net enrollment of 841, making a total enrollment of the two groups of 1,196.

In each of these cities Mr. Keller presented his series of six lectures on steel and its treatment.

Mr. Keller's cordial reception in these cities; the splendid enrollment and the numerous complimentary remarks received at National headquarters, showed that the society was accomplishing a worthwhile piece of work. This activity was self-supporting.

Changes in the Constitution

At the annual meeting of the society held in Detroit last year the Constitution and By-Laws Committee presented a number of changes in the Constitution. These were printed in full in the October, 1927, issue of the Transactions. The most important adopted at that time provided for the elimination of the associate member classification, and that all present associate members of the society should become members of the society with the consequent reduction of dues from $15.00 to $10.00.

Annual Report of the Recommended Practice Committee

The Recommended Practice Committee has had during the last year fifteen subcommittees in operation. These fifteen committees have concentrated their efforts on a number of problems, several of which have been completed and published in the Handbook.

One hundred and twenty-four members are serving or have served the society this year on these technical committees, which gives an average of eight members for each committee.

Three of the committees conducted their work entirely by correspondence and informal conferences. The other twelve committees held a total of twenty-seven meetings with an average attendance of five members present at each meeting.

The work accomplished by these committees consists of ten new reports and recommended practices and three revised practices, totaling in all 58 pages in the Handbook. Also there are included in this section 26 pages by authors which makes an increase of 84 pages in the Steel Section of the Handbook.

The co-operative arrangement between the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers and the American Society for Steel Treating has added a valuable nonferrous section to the HANDBOOK. In this section are 90 pages on twenty-six different subjects. Twenty-five of these subjects consisting of 77 pages represent the splendid accomplishments of the Institute of Metals Nonferrous Data Sheet Committee for its first year's activity, under the chairmanship of R. S. Archer. Therefore, the HANDBOOK contains in both sections 156 pages of new material on forty new subjects.

The Recommended Practice Committee has at the present time twenty-nine subjects that have been either assigned to sub-committees or authors and are in process of preparation. It is expected that several of these problems will be completed within the coming year.

The Institute of Metals Committee on nonferrous data sheets has in process an extensive program comprising several phases of nonferrous metallurgy. This material which will be ready for publication within the next year will round out the Nonferrous Section of the HANDBOOK, making it a very valuable source of information on nonferrous subjects.

1929 EDITION OF THE HANDBOOK

The first copy of the American Society for Steel Treating HANDBOOK in bound form, or the 1929 edition, was completed on August 22, 1928. Distribution to the membership started about September 1, 1928. This new HANDBOOK contains 14 sections, including 100 different technical subjects which total 593 pages.

The present plans are to issue the 1930 edition of the American Society for Steel Treating HANDBOOK early in 1930, probably in March or April of that year.

The society has been issuing data sheets for the HANDBOOK since December, 1923, or approximately 5 years. During this period the total expenditure for conducting this work, including printing, paper, postage, salary, committee activities, etc., has been $45,759.36. The income derived from this activity has been $10,343.42, which gives a total of $35,415.94 expended by the society for producing the HANDBOOK.

This, of course, does not include the great amount of valuable time devoted in the interest of the HANDBOOK and welfare of the society by the hundreds of members who have contributed to its making. These valuable contributors find their greatest reward in being able to be of service to their fellow members.

TRANSACTIONS

The total editorial production for the first 14 volumes of the TRANSACTIONS is shown in Table II, with a total of 13,256 pages. The number of pages, however, in volume 14 is estimated inasmuch as volume 14 continues through December, 1928.

During the year from September 1, 1927, through August 31, 1928, 12 issues of the TRANSACTIONS have been published, containing 82 papers, a total of 2,164 pages. This compares with 84 papers or 2,114 pages, last year.

Table II

Total Editorial Production

Transactions

Vol. 1	840	pages
Vol. 2	1,238	
Vol. 3	1,000	
Vol. 4	752	
Vol. 5	642	
Vol. 6	816	
Vol. 7	816	
Vol. 8	892	
Vol. 9	992	
Vol. 10	1,036	
Vol. 11	1,042	
Vol. 12	1,050	
Vol. 13	1,090	
Vol. 14	1,050	
Total	13,256	

Handbook

	Pages	Subjects
1924	110	16
1925	129	21
1926	114	13
1927	86	10
1928	156	40
Total	593	100

In dividing the papers published into 3 classes, practical, semi-technical and technical; 666 pages or 31 per cent were of the practical class; 250 pages or 11.5 per cent were of the semi-technical class; and 687 pages or 31.5 per cent were of the technical class. In addition to the per cents as indicated for these 3 classes, there were printed in the TRANSACTIONS 562 pages of Patent Reviews, Engineering Index, News of the Society, News of the Chapters and Items of Interest, which is 26 per cent of the total. The total number of pages published for the year, including advertising and editorial matter, is 3,254.

During the 12 months from September 1, 1927, through August 31, 1928, a total of 65,750 copies of the TRANSACTIONS were prepared at a cost of $44,272.86, which results in an average cost of 67½c per copy.

REPRINTS

On September 1, 1927, we had on hand 23,252 reprint pamphlets taken from the TRANSACTIONS. During the year, 25,460 reprints were distributed to the membership. We have on hand now 10,192 reprints available for distribution.

Each month reprints of the articles appearing in that issue of the TRANSACTIONS are prepared, a portion of which are sent to the author or authors of the paper and the balance kept on file for distribution to the membership, as requested.

A special edition of 500 copies, of the second Campbell Memorial Lecture,

presented by Dr. Zay Jeffries, was prepared and distributed, principally to a selected list of close friends and colleagues of Professor Campbell.

Preprints

At the last Convention 45 papers were presented, 23 of which were preprinted. This year's Convention has scheduled 41 papers for presentation, 31 of which have been preprinted and distributed on September 1, 1928, to those members requesting them. The total number of pages in the preprints for 1927 was 475, whereas the total number for 1928 is 666.

The Campbell Memorial Lecture to be presented by Dr. W. H. Hatfield has been preprinted and will be distributed to those in attendance at the close of his lecture. This preprint contains 160 pages.

Meetings of the Publication Committee

The Publication Committee held an all-day meeting on February 15, 1928, the day prior to the Semi-Annual Meeting of the Society, at which time important matters pertaining to the work of the Committee were discussed in detail.

1927 Convention and Exposition

The Detroit Convention of the American Society for Steel Treating brought forth a total of 45 technical papers, 23 of which were preprinted, thus assisting materially in the large amount of valuable discussion which was contributed.

Meeting concurrently in Detroit were the annual meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers; the annual meeting of the American Welding Society and a two-day meeting of the Production Division of the Society of Automotive Engineers. With these four national technical societies in session at the same time, the very proper name of National Metal Week was applied to the activity.

It might be interesting to note at this time the following remarks made by *Iron Trade Review*. Commenting editorially under the title "Making National Metal Week Permanent," they said:

"Once again the American Society for Steel Treating has brought to a successful conclusion an annual convention of record-breaking proportions. National Metal Week most aptly depicts the activities which took place in Detroit last week. Meeting with the Society in simultaneous meetings were three other national technical organizations interested in metals, their production, fabrication and treatment, with the result that the total convention attendance was the largest gathering of metals experts ever brought together in this country or the world.

"The steel treaters may well take pride in their most recent achievement. Never before have their technical sessions been so well attended—several meetings attracting between 400 and 500.

"Setting a precedent was the fact that the convention and exposition were arranged and conducted without assistance of local committees, all details being handled by the society's national office. Two local members merely aided in advisory capacity. This conservation of time for members

of the local chapter is to be recommended highly, and is a plan which other technical societies will do well to investigate and adopt.''

In an eleven-page survey of the exposition and convention of the society entitled ''National Metal Week at Detroit a Notable Event—Many High Grade Technical Papers—Exposition Sets New Record,'' the *Iron Age* comments as follows:

''Surpassing in significance and size its previous conventions, the American Society for Steel Treating at its ninth annual convention and exposition brought together a gathering of American technical men which, in a way, was epochal. Associated with that organization were the American Welding Society, the Society of Automotive Engineers, and the Institute of Metals, so that in all the over 3,150 society members assembled there included 2,533 steel treaters, 425 members of the welding society, 105 nonferrous men and about 100 automotive enginers. The steel treaters' registered attendance was approximately 55 per cent of the total membership.

''A high standard characterized the technical programs. Several new developments in metallurgy and heat treatment were made public.

''Imposing in its diversity, comprehensiveness and size was the Steel and Machine Tool Exposition, to be known hereafter as the National Metal Exposition.

''No former exposition of the society has equalled the one last week at Detroit. Both the magnitude and diversity of exhibits were the features, as well as the progress reported visibly in many lines. The floor space actually rented was 93,000 square feet against 87,000 square feet in Chicago last year. The arrangement, however, surpassed in convenience and in perspective more recent displays. With nearly 300 exhibitors, many of them new ones, it is possible here only to give those who were not present a general review of the exposition as a whole. The show has reached such proportions that detailed reports are not feasible.''

ANNUAL REPORT OF THE TREASURER

J. M. Watson, *Treasurer*

An unaudited profit and loss statement of the American Society for Steel Treating taken for the period from January 1 to August 31, 1928, and the balance sheet as of August 31, 1928, continue to show a satisfactory condition in the financial status of the Society.

The financial statement shows the income of the Society for the first eight months of 1928 was $87,419.85 and expenses were $86,733.62, leaving an excess of income over expense of $686.23, exclusive of the 1928 Convention income and expense. The net worth as of August 31, 1928, after deducting advance receipts for this year's Convention was $156,175.37 or approximately 30 per cent greater than at the same time last year.

The balance sheet shows the following:

Cash on hand and in banks	$ 49,299.60
Bond investments	126,557.99
Accounts receivable less allowance for bad debts	4,192.55
Inventory and office furniture and fixtures	8,515.16
Prepaid expenses for 1929 Convention	3,537.62
	$192,102.92

A claim against these assets exists in the amount to be refunded to the chapters for dues received in August	$ 1,098.28	
		$191,004.64
There is also included in the above cash accounts the advance receipts for the present convention	$ 54,350.60	
less expenses paid to August 31	19,521.33	
		$ 34,829.27
As the services to be rendered for these advances have not yet been completed and the majority of the convention charges have not been paid, a deduction of this amount should be made and the result will give the Society's present net worth		$156,175.37

The following comparisons with previous years may be of interest:

	Amount Paid to Chapters		*Total Assets of the A. S. S. T.*
For 1921	$ 7,244.22	As of Dec. 31, 1921	$ 16,520.90
1922	10,051.95	Dec. 31, 1922	31,391.31
1923	12,751.45	Dec. 31, 1923	46,821.30
1924	14,194.14	Dec. 31, 1924	62,116.65
1925	16,039.63	Dec. 31, 1925	87,196.60
1926	20,185.83	Dec. 31, 1926	114,451.27
1927	22,390.43	Dec. 31, 1927	158,396.88

It is confidently expected that the financial report at the end of the present fiscal period will again show a satisfactory increase in the total assets of the Society.

During the past year from September, 1927, $50,000.00 has been invested in additional high grade securities by recommendation of the Finance Committee and the authority of the Board of Directors.

New York Power Co. 4½'s	$5,000.00	
New England Gas & Electric 5's	5,000.00	
Chicago, R. I. & Pacific 4½'s	5,000.00	
Southwestern Power & Light 5's	5,000.00	
Youngstown Sheet & Tube 5's	5,000.00	
Philadelphia Co. 5's	5,000.00	
Indiana Service	5,000.00	
U. S. Radiator 5's	5,000.00	
Firestone Cotton Mills 5's	5,000.00	
St. Louis & San Francisco 4½'s	5,000.00	
		$50,000.00

Distribution of Society's Investments

Liberty Bonds	$28,000.00	22.00%
Municipal Bonds	1,000.00	.80
Trust Securities	30,000.00	23.70
Railroad	15,000.00	11.80
Industrial	28,000.00	22.00
Public Utility Bonds	25,000.00	19.70
	$127,000.00	

These are exceptionally good investments and were thoroughly investigated before being bought. Before securities can be purchased, it is necessary to have the unanimous consent of all members of the Finance Committee.

The Society is endeavoring to maintain a healthy financial condition and at the same time render a maximum of service to the members. This year has seen the revision and publication of the Data Sheets in a bound book, with an attendant outlay of approximately $8,000.00. Extension lecture courses were organized the latter part of 1927 and again this fall to further assist our members and the steel industry in general. The Library and Employment Service activities have also been increased and added to.

It may be interesting to note the result of an analysis of the average

amount received from all classes of members of the Society and the cost of actual direct service rendered per capita to these members in return for the year 1927.

The present membership figures show:

4158	Members	(Annual Dues $10.00)	$ 41,580.00	
17	Associate Members	(Annual Dues 15.00)	255.00	
444	Sustaining Members	(Annual Dues 25.00)	11,100.00	
214	Junior Members	(Annual Dues 2.50)	535.00	
11	Honorary and Founder Members	(no dues)		
	Result—Average Dues Received			$11.04
Total expenditures in direct service to members made in 1927, as taken from the audited report.			$116,270.54	
	Result—Service rendered each member			$24.005

Another interesting point in the division of the dues follows:

In 1927 the gross dues received amounted to $54,221.82. The amount refunded to the chapters was $22,390.43 or 41.1 per cent. This, I believe is a record and is an outstanding reason for the excellent financial condition of the local chapters and one that allows them to secure speakers for their meetings who are authorities in their respective branches of activities.

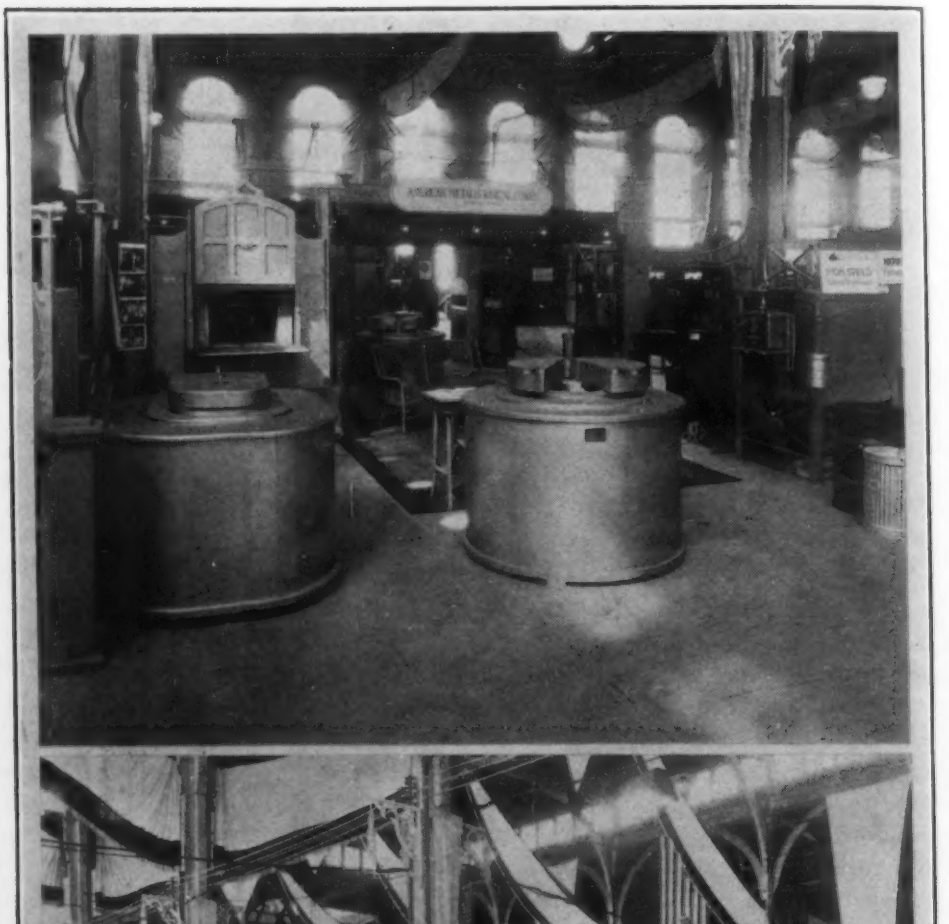
Because the present financial condition of the Society is sound and future prospect bright, plans for improved and additional service to members are being actively worked upon and can be confidently expected in the near future.

I want to express my very deep appreciation of the excellent counsel I have had from Dr. Zay Jeffries, our former treasurer. Having been associated with him for five years in the financial work of the Society, I can assure the members that the healthy condition of the Society is in no small measure due to the care that Dr. Jeffries and his predecessors have used in the administration of the organization's funds.

My thanks are also due to Mr. Eisenman and the personnel at the Society's headquarters in Cleveland, especially Mr. C. W. Ohlson, for their valuable assistance.

The next order of business was the report of the nominating committee, which held its meeting on Monday morning. This report was made by the chairman of the National Nominating Committee, Dr. Wm. E. Ruder. The slate as selected by the nominating committee appears upon page 645 of this issue of the TRANSACTIONS. After Dr. Ruder's report had been submitted and accepted by the membership, President Hughes introduced each of the men so nominated to the assembled members.

The next order of business was the report of the Constitution and By-laws committee, which in the absence of Chairman S. M. Havens, was presented by H. J. Stagg, a member of the committee. Two matters were presented to the membership which after a short discussion, principally by way of explanation, were unanimously accepted by the members. These proposals are as follows:



VIEWS OF THE EXPOSITION

Proposed Changes to the Constitution

Amendment No. 1. Amend Article VII, paragraph 7, to read as follows:

Section 7. Any member whose dues to the Society shall remain unpaid for a period of one calendar month after final bill for same shall have been mailed to him, directed to his last post office address as the same appears on the records of the Society, shall automatically cease to be a member of the Society.

Amendment No. 2. Add to Article VIII, the following new Section.

Section 7. The Board of Directors may at a regular or special meeting of such Board, duly called and held in accord with the By Laws of the Society, fix a date on which dues of all members shall become payable. In like manner the Board may change such date, or provide that dues shall be computed from the date of election to membership. Provided, however, that nothing in the section shall authorize the Board to alter the total amount of the dues that shall be paid by any member in any successive twelve months and that in the event that the Board shall take any action under this Section all dues shall be prorated so that the total amount of dues paid by any member in any successive twelve months shall not be altered.

President Hughes then presented to Dr. R. H. Patch, chairman of the Philadelphia Chapter, the president's bell and gavel, which was originally presented in 1926 to the Lehigh Valley Chapter by the then president Robert M. Bird. We quote President Hughes' remarks in the presentation of this bell.

"One of the formalities which has occurred at the annual banquet for the last two years has been the presentation of the President's bell. This bell was awarded first by the then President Bird and has been awarded to various chapters for certain meritorious and useful things which these chapters have done for the growth of the Society and the furtherance of its objects, exceptional furtherance of its objects during the past year. There are no provisions in the Constitution or By-Laws that shall hamper the president in the selection of the chapter that shall receive this glorious relic, and therefore this is one of the embarrassments, I suppose. I now proceed to get into disgrace with every member of every other chapter in the United States excepting the one that gets the

bell. The president gets the hammer,—and we have a hammer that goes with the bell.

"Therefore, without further formality, it gives your president a great deal of pleasure to bring the bell back from the Pacific Coast, where it has remained untarnished for the past year, and to award it to Dr. Patch, who is chairman of the Philadelphia

DR. WILLIAM H. HATFIELD
Edward De Mille Campbell Lecturer for 1928

Chapter, not entirely because they have been our hosts this year, although we do wish to recognize the great help that the Philadelphia Chapter and its members have been to us in holding this convention, but primarily for the work which has been done by the Philadelphia Chapter in co-operation with Temple University in putting on its educational metallurgical courses for the advancement of science in the Philadelphia district. Therefore, Dr. Patch,

on behalf of the Society and on my own responsibility, I take great pleasure in presenting you this bell. (Applause) I think it is perfectly proper that in this city where a certain very famous bell rung out so many years ago, Philadelphia should have a new bell without a crack in it."

At the close of the annual business meeting, President Hughes turned the meeting over to past president Dr. George K. Burgess, director of the Bureau of Standards at Washington, who served as chairman for the Edward de Mille Campbell Memorial Lecture —which was ably presented by Dr. W. H. Hatfield of Sheffield, England. Dr. Hatfield's discourse was listened to by about 600 members and guests of the Society. The subject of Dr. Hatfield's lecture was "The Application of Science to the Steel Industry." At the close of the meeting each person in attendance was given a printed copy of Dr. Hatfield's lecture, which, due to its length, was not presented in full by the author. This preprint contained 160 pages and will appear serially in the TRANSACTIONS.

The Wednesday afternoon technical session, under the chairmanship of Dr. Zay Jeffries, assisted by Charles McKnight as vice-chairman, consisted of a joint meeting of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers and the American Society for Steel Treating. Five papers had been prepared and scheduled for this session. They are as follows:

2:30— 3:00 P. M.—*Notes on Smoothing and Etching*—H. B. Pulsifer, The Ferry Cap and Set Screw Co., Cleveland.

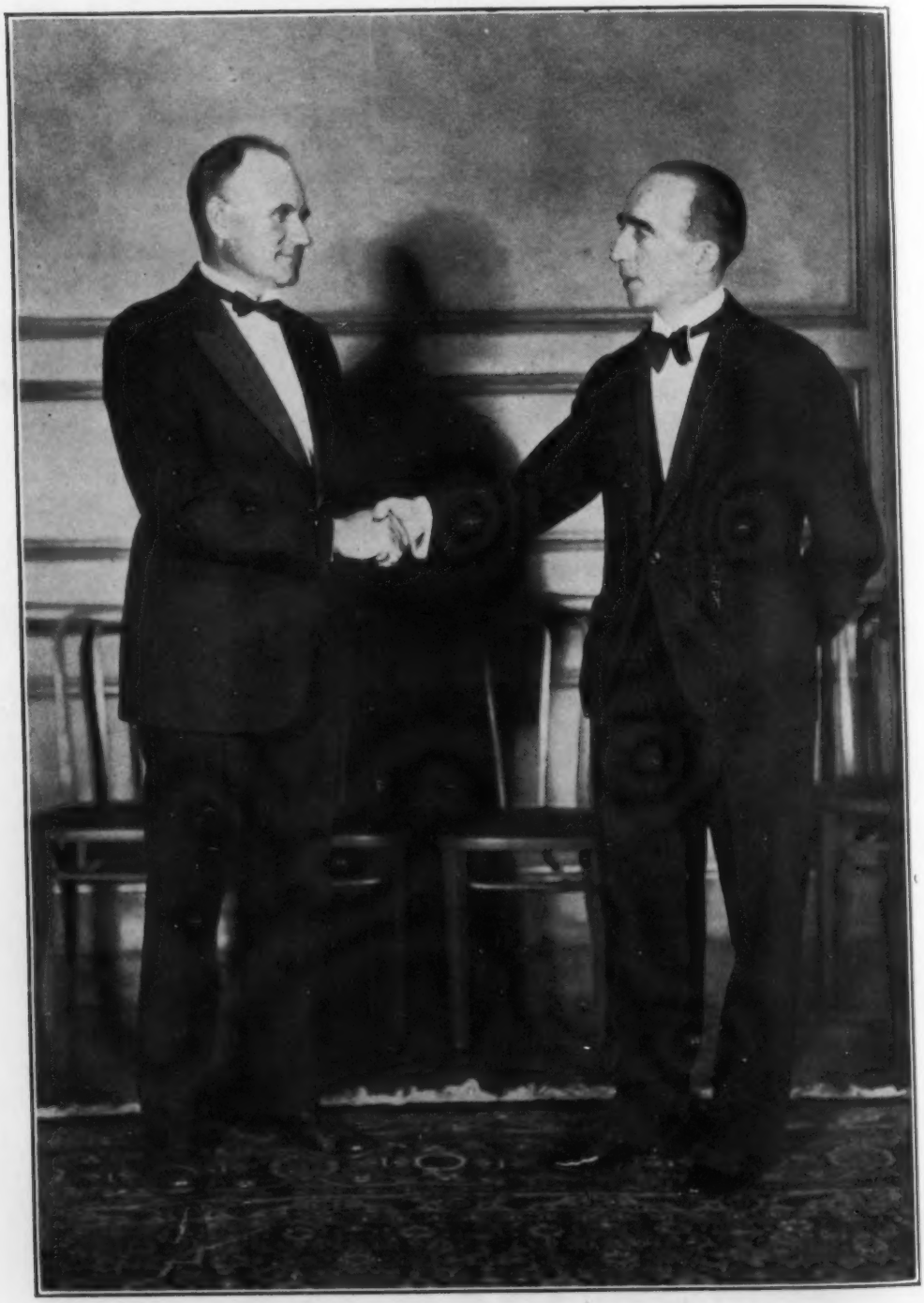
3:00— 3:30 P. M.—*Further Observation on the Microstructure of Martensite*—Francis F. Lucas, Bell Telephone Laboratories, New York City.

3:30— 4:00 P. M.—*Treatment and Structure of Magnesium Alloys*—John A. Gann, Dow Chemical Co., Midland Mich.

4:00— 4:30 P. M.—*Neumann Bands in Ferrite*—C. H. Mathewson, Professor of Metallurgy, Yale University, New Haven, Conn.

4:30— 5:00 P. M.—*A Study of the Constitution of High Manganese Steels* —V. N. Krivobok, Carnegie Institute of Technology, Pittsburgh.

The first, third and fourth papers were arranged for by the Institute of Metals and the second and last papers by the A. S. S. T. Each of the papers was presented by its respective author and called forth much valuable and interesting discussion. It is significant to note that just prior to the adjournment of the meeting Chairman Dr. Jeffries made the following remarks: "In bringing the meeting to a close, I cannot refrain



DR. ZAY JEFFRIES AND DR. W. H. HATFIELD

DR. GEORGE K. BURGESS
Chairman—Edward DeMille Campbell Lecture

from mentioning that this meeting has been of a very high order, the papers have been splendid and splendidly presented, the discussion has been to the point and intelligent and I think that I have never been in a room in my lifetime where so much brains and experience in metal science has been represented as has been here this afternoon."

THURSDAY, OCTOBER 11

The seventh session of the Convention was called to order at 10 o'clock by Chairman Dr. Albert Sauveur. Dr. Sauveur was assisted by J. P. Gill as vice-chairman. Five papers were scheduled for presentation at this session and were presented in the following order:

10:00—10:30 A. M.—*On Oxygen Dissolved in Steel and its Influence on the Structure*—M. A. Grossmann, Central Alloy Steel Corp., Canton, Ohio.

10:30—11:00 A. M.—*Surface Cooling of Steels in Quenching*—H. J. French, G. S. Cook and T. E. Hamill, Bureau of Standards, Washington, D. C.

11:00—11:30 A. M.—*Tungsten Carbide, a New Tool Material*—S. L. Hoyt, General Electric Co., Schenectady, N. Y.

11:30—12:00 A. M.—*Austenite Decomposition and Length Changes in Steel*—Edgar C. Bain, U. S. Steel Corp., Kearney, N. J., and Willis S. N. Waring, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.

On the Nature of Martensite Crystals—Dr. Kotaro Honda, Tohoku Imperial University, Sendai, Japan. (By Title.)

Each of the papers was presented by its respective author with the exception of the last paper which was presented by title. H. J. French presented the second paper on behalf of his colleagues Messrs. G. S. Cook and T. E. Hamill. This session was of outstanding significance in that the papers presented dealt with subjects of primary importance to persons interested in steel and its heat treatment. While a time schedule had been established for the presentation and discussion of each paper it is significant to note that the discussion upon these papers continued until 1:15 P. M., which was one hour and fifteen minutes beyond the actual time schedule. Each of the papers had been preprinted, but will appear in early issues of the TRANSACTIONS, together with the discussions which took place at this session.

Mr. J. Fletcher Harper, past president of the Society, assisted by Miss Francis H. Clark, presided at the Thursday afternoon session which opened at 2:30 P. M. The four papers scheduled for presentation at this meeting were as follows:

2:30— 3:00 P. M.—*Torsional Modulus of Carbon Steel, Phosphor Bronze, Brass and Monel Metal*—William P. Wood, University of Michigan, Ann Arbor, Mich.

3:00— 3:30 P. M.—*Silicon-Manganese Steels with Chromium Additions for Engineering Applications*—A. B. Kinzel, Union Carbide and Carbon Research Laboratories, Long Island City, N. Y.

3:30— 4:00 P. M.—*Evaluation of the Stability of Metals at Elevated Temperatures from Expansion and Short-Time Tensile Test Data*—Albert E. White and Claude L. Clark, University of Michigan, Ann Arbor, Mich.

4:00— 4:30 P. M.—*Cloudburst Process for Hardness Testing and Hardening*—Edward G. Herbert, Edward G. Herbert, Ltd., Manchester, England.

The first two papers were presented by their respective authors, the third paper was presented by the senior author and the fourth paper was presented by Mr. R. B. Lewis. As in the case of all of the papers which had been presented at each of the sessions of the week, the papers at this session were thoroughly discussed, both in written and oral form.

ANNUAL BANQUET

In accordance with the custom which has been established by the Society the annual banquet was held Thursday evening in the

ballroom of the Benjamin Franklin Hotel. About 500 members and guests were present for this annual function and following an unusually good dinner the guests were entertained by toastmaster Charles E. Carpenter, president of the E. F. Houghton Company, and several speakers who were on the program. The past officers, honorary members and guests who were seated at the speakers' table were as follows: W. H. Eisenman, R. H. Patch, L. D. Hawkridge, F. P. Gilligan, Dr. John A. Mathews, Dr. O. E. Harder, R. D. Wyer-

DR. OSCAR E. HARDER

DR. RALPH L. DOWDELL

Howe Medalists for 1928

bacher, Dr. Zay Jeffries, Dr. W. H. Hatfield, F. G. Hughes, Charles E. Carpenter, Edward P. Warner, J. Fletcher Harper, Douglas Mulloch, R. M. Bird, Dr. Albert Sauveur, J. M. Watson, Dr. A. E. White, W. H. Phillips, T. D. Lynch and J. H. Nead.

President Hughes opened the speaking program at 9:10 P. M., and extended words of appreciation to all those who had taken part in the work of the Convention, the Society and especially the Institute of Metals Division and the American Welding Society. He then turned the meeting over to the toastmaster Charles E. Carpenter who after some preliminary remarks introduced past president R. M. Bird, who presented to our last past president J. Fletcher Harper the past president's medal. Following this, Toast-

master Carpenter called upon President Hughes for the presentation of the Howe Medal to Dr. Oscar E. Harder and Dr. Ralph L. Dowdell for their paper entitled "Decomposition of Austenite," which in the judgment of the awards committee, was considered the paper of highest merit published in the TRANSACTIONS of the Society for the year 1928. After the presentation of the Howe Medal, Toastmaster Carpenter introduced Honorable Edward P. Warner, assistant secretary of the Navy, who gave a very interesting talk upon the subject of aeronautics. Mr. Warner's address is printed in full as follows:

Four hundred thirty-six years ago, not to go too far back into history in the beginning of an aviation paper, news of the existence of this continent was first brought to the courts of Europe. About four years ago, in fact, exactly four years ago tomorrow, a new voyage of discovery was started from European shores, and it was perhaps something more than coincidence that the day selected for the inauguration of the flight of the airship Los Angeles from Southern Germany to New Jersey was the date which we have selected to celebrate in honor of the memory of that illustrious discoverer who first visited American shores and returned with the story. And now Columbus Day has come again and again a voyage which should take a notable place in history is under way. Tonight, somewhere off the coast of Spain, there is a vessel which set forth this morning from a point in central Europe that takes some 36 hours to reach by rail from the Spanish frontier. On Sunday morning, if all goes well—and certainly we have no reason to expect that it will not—it will come to rest in front of the hangar at Lakehurst, some 40 miles from this hall,—the first commercial crossing of the Atlantic by air, the first aerial trans-oceanic voyage in which paying passengers have been carried, in which an approximate schedule has been announced some time in advance and approximately adhered to. There has, to be sure, been no effort and no intention of operating on an exact schedule, and that would be somewhat abnormal in dealing with a craft so new.

The flight that started this morning and the flight that brought the Los Angeles to America for delivery to the Navy four years ago are alike in certain respects and, in particular, they have the common feature that they are both triumphs of the metallurgical industry. Without the work of the members of the American Society for Steel Treating and those others who, here and abroad, are engaged in kindred endeavor in metallurgical fields, there might be aircraft of some sort, but certainly there would be no airship like the one that is now already embarked upon the task of paying us a visit.

The beginning of the airship goes back a quarter of a century, at least, in something like the present form. Progress was very slow at first. It was only after the lapse of ten or twelve years that very rapid strides began to be made, and the time when real progress appeared and when

it began to be possible to look forward to the rigid airship as a truly commercial craft and as a truly useful commercial instrument was the time when the use of pure metallic aluminum, or the nearly pure metal, was abandoned in favor of the use of an alloy which gains increased strength and more satisfactory properties from treatment in your laboratories.

To the airship, that has been absolutely indispensable. Without duralumin or some other of the modern light alloys that have been created in the past two or three decades, the airship as we know it today could not possibly exist.

For the airplane, kindred endeavors on your part and that of your associates has been almost indispensable, although we have perhaps been somewhat slower to realize it. I was just looking over some of my old aeronautical books and pamphlets the other day and I came across a prophecy written a little less than two decades ago that the airplane of the future will be built in the carpenter shops of the future. It has taken us almost twenty years to set that prophecy at naught, but it is very clear now that although the carpenter shop still has a part to play, it is a declining and a waning part.

I do not want to weary you with statistics or with technical detail, but it is sufficient to take two or three landmarks in recent aeronautical history and, not to go into detail at all, to show how very rapid has been the trend away from aircraft as the primary concern of the worker with forest products towards aircraft as the primary concern of the metallurgist and of the steel treater and of those engaged in the heat treatment and the fabrication of other metals.

Ten years ago or a little less than that, just upon the morrow of the Armistice, there was so little metal in a typical airplane that the amount could almost be neglected, excepting that which entered into the engine. There were bolts and fittings that held the parts together and other minor elements of the structure, but it was essentially a wooden structure, and a very satisfactory structure it seemed at that time.

It took only as long as the period required for a verdant freshman to become an arrogant senior for wood to give way to metal, to steel or aluminum, but usually to steel, in about half the structural elements of the plane, and already, five years ago, it was the common and almost the universal practice to fabricate airplane bodies out of some metallic material, and usually a ferrous metal.

Last year another step in the conversion from the wooden to the metallic construction had become so general that it could, in turn, be regarded as typical. Struts and tail surfaces and other minor structural elements had a year ago, in most cases, and have now in still a larger majority of all aircraft, been converted into the metallic form. What we shall see two or three years hence it is perhaps dangerous to prophesy, but I think it is quite safe to say that that wing structure, which is still of wood in most instances, although of metal in a growing number, will be thrown into the metallic form in more and more cases and finally in very nearly if not quite in all, and that a structure which, including the power plant,

was perhaps half of metal only nine years ago and is perhaps three-quarters metal now, will become purely metallic within a very few years except for minor elements of rubber, of upholstery, or of fabric.

While I was waiting outside for the first gun to be fired tonight, I picked up a copy of the Steel Treaters' Daily to try to learn from reading your newspaper a little more about what manner of an audience I was to address, and I came across a sentence in the editorial of the day which I thought was worth quoting, if only to show how far the aeronautical people are ahead of the rest of the world.

"Those in attendance at this convention," says your editor, "cannot fail to apprehend as never before has been possible the vastly important roles played by metallurgy and metal fabrication in the great industrial pageant now spread before Americans in their country's economic developments and achievements."

You have all been in attendance throughout the convention and I presume you are all now fully instructed upon that subject, but we of the aeronautical industry, or we who are interested in aeronautics, did not have to come to the Steel Treaters' Convention to be very sure for our own section of American industry of the vital importance of metal fabrication and of the developments that the last ten years have seen in that art. We recognize only too clearly how dependent we are upon those developments and how heavily we must continue to lean upon you of the metal trades for a continuation of the progress and growing efficiency in aircraft of all types which the last decade and the decade before that have seen.

From you we get most of our materials now; from you in the future we shall get, I am sure of it, very nearly all. And it is perhaps appropriate that you ask in reply, "What do you get from us?"

Well, of course, the answer might be that there is a business relationship and that the metal trades, the steel industry and that industry which manufactures and sells light alloy profit by relationship with the manufacturer of aircraft in a purely commercial way. But I should be very loath to admit that that was the only relationship that existed, and I am afraid I could not build up a very strong case for a very profound interest on the part of the metal industries in aeronautical development if it were only the present procurement of metal parts and of metallic materials by the aircraft manufacturers that you had laid before you as a possible means of extracting your interest.

I have already remarked that I did not want to give statistics, and I will keep myself to very few figures, but one or two are perhaps expressive, even though they do not magnify the importance of the aircraft industry as much as I might desire.

In the naval service at the present time we buy something over 300 new airplanes a year, which means, roughly speaking, about 500 tons of aircraft structures and engines. I will not break that up into its several parts, the several metals and of wood and of other materials, but when we take all the aircraft in the United States together, I think it works out

that at the present time the aircraft industry is consuming something like 1/500 of one per cent, or maybe it is 1/1000 per cent of the country's output of ferrous metals, and something like one-quarter of one per cent or a little less of the output of light alloys, including power plants and all accessories that go into the aircraft—not a very great market to attract your industry, at first sight. It will grow—make no mistake on that point—but I, for one, hardly dare, in fact, I am very definitely unwilling to be so optimistic as to suggest that it will ever be a major part of your market or that the sale of metals for use in aircraft and aircraft engines will ever be large enough to cause vital concern in time of peace to the metal fabricating industries. It will grow, but I am either too much lacking in optimism or too conservative or something to look forward to the time when aircraft will be built in millions, like Ford cars. I can very easily look forward to the time when they will be built, not in hundreds or in thousands, as today, but in tens of thousands, through a steadily continuing growth. I think that we can all expect this with confidence. But still, measured in tonnage, the total consumption of metals, or any other materials, in airplanes, is going to be rather small.

But I do not think that you are content, and I know I am not content to leave the matter there or to say that that is your only interest. In the first place, speaking as a representative of one of the departments especially charged with the national defense, I feel very sure that those who are active in the metal working, metal fabricating, and metal manufacturing trades have a very strong concern in making sure that there will be available in case they are ever needed in military emergency, the very best materials that are to be had anywhere in the world for incorporation in American aircraft and in unlimited quantity, or, if that be too broad an expression, in quantity fully adequate to any possible demand. And while I am loath to talk of the possibility of future wars, the conceivable, the probable industrial demands, the burden and the responsibility that would be thrown upon American industry in the unhappy event of any future international hostilities is a matter with which both those in the government service and those in industry must have some reckoning as long as we are obligated to keep up a national defense organization at all.

Again, I steer off from figures, but I need not go into statistical detail to convince all of you who have seen what has been done with aircraft in the last few years and who remember the part that aircraft played in the closing years of the Great War, to convince you that the demand in case of another war emergency would be magnified, not five, ten, or twenty fold, but one hundred or two hundred fold or more over any peacetime need of the present day, at least, for aircraft and their parts.

Under those circumstances, the provision of materials would be a real problem for the industry, materials, remember, highly specialized in their nature and in their treatment, and the problem is one that should have your earnest thought from time to time. Even as in Great Britain and here, in 1915 and 1916 in Great Britain and in 1917 and 1918 in both countries, the provision of aircraft materials, even in that early day of

aerial operations, had become a very serious problem, and the organization of an adequate spruce supply to keep the aircraft of the allied countries upon the front—and they had a similar problem on the other side of the lines—was a very grave one indeed, requiring provision to be made on a grand scale, not at the fighting front but in the Northwestern United States, six or seven thousand miles away from the fighting front, where spruce was being brought out, inspected and fabricated for ultimate incorporation in fighting planes. There would be no problem of spruce in the future, but there might be a very grave problem of certain light alloys and of certain materials entering into metallic aircraft and of their fabrication.

But, laying that aside and thinking only of the conditions of peace and of relationships that now exist, there are other reasons than the mere magnitude of the aircraft industry and its potential market as to why you should be, and I think are, very definitely interested.

The first and the simplest argument that I can offer for your interest is that everybody is interested in aviation. In the last eighteen months or so, since Colonel Lindbergh flew to Paris, we who have had the good fortune to be connected in any way with aeronautics have had the happy feeling that everybody wants to know something about our job, that it is an industry of universal concern. But I do not rest the case there. What is of more immediate and practical and continuous concern is that the aircraft industry and the demands of the aircraft industry, quantitatively small though they may be, are a very definite incitement to research and to the development of better materials, an incitement to research on methods of structural analysis, on methods of fabrication of metals, on the strength and heat treatment of the metals themselves, on fatigue testing, on the development of new alloys, on corrosion, and on a dozen other topics.

You may say that all those things were important before aircraft existed, and that is true, in a sense, they were, of course, but aviation has the great advantage, from the point of view of industries which supply materials for use in airplanes, that it is the extreme case, it is the "must" case, where we have to have a high degree of efficiency or we can not operate at all with safety. So, from the demands of the aircraft industry during the World War and since, there have resulted researches which might have been much longer delayed or might not have been carried on at all without the needs of the airplane operator to spur the laboratory forward.

We have developed materials, or perhaps I should say you have developed them, for use in aircraft, and you have found those same materials available for motor truck bodies and for roller skates. There have been by-products on a grand scale from the aircraft industry, and while here I will not venture the figures, even if you wanted to listen to statistics all night, I am sure that there is a very great consumption of high-strength alloys and of light alloys which would not be possible if there had been no aviation industry and no crying in the wilderness from the designer and builder of airplanes and airships demanding that the metal industries give him

something not only a little better, but much better, in order that he could fly at all.

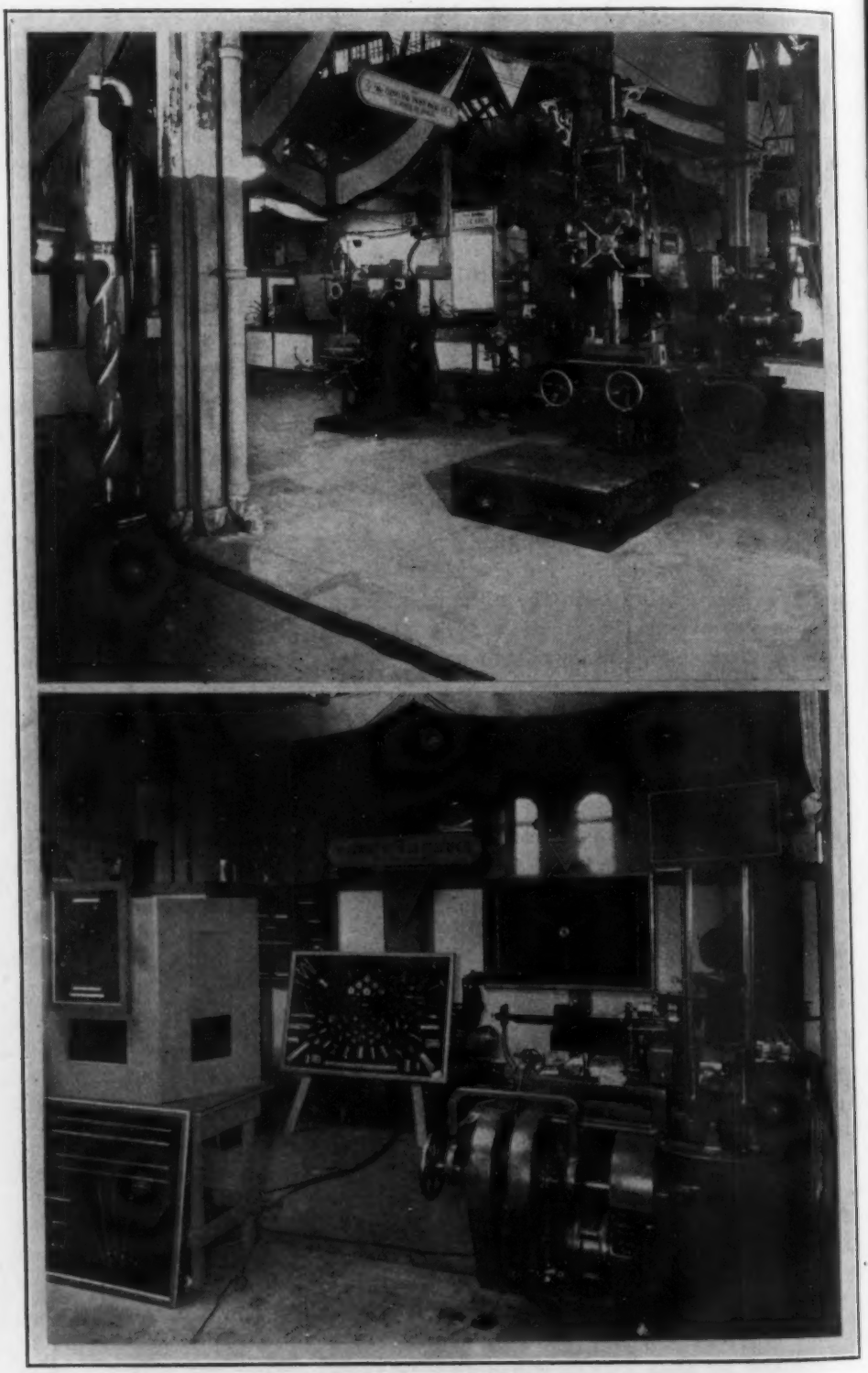
That research has gone on in many hands. I said first we had done it, speaking for the aeronautical interests as a whole, and then I said that you had done it, but both are right. It has been carried on jointly by the metal industries, by the aircraft industry, and by the government working in very close harmony and cooperation.

I do not know how many of you are resident here in Philadelphia and I do not know how many of those who are either resident here or who have come here for the days of this convention have had the opportunity or taken the trouble to go out to the Navy Yard and visit the Naval Aircraft Factory. I am sure that anyone who has done so, who has been through that plant, has been well repaid and that you have not left without a certain admiration for the work that has been done, both by the officers of the naval service and by the civilians working in naval employment, both in the experimental construction of aircraft parts and accessories and in the testing and development of materials ultimately to enter into aircraft structures.

We look with considerable pride upon the studies that have been made on corrosion of light alloys and on the working of light alloys and the methods of assembling both the aluminum compounds, aluminum alloys, and ferrous materials at that institution, started under pressure of a war demand ten years ago. We want to carry on that work, there or elsewhere, and we expect to carry on research on metals as well as on a great many other things. We expect you to continue to carry on researches bearing on the application of your materials to aircraft and to profit mightily from your efforts.

It is not news to anybody who is in this industry or, for that matter, in almost any other industry nowadays, that research requires both brains and money. The government laboratories I think have a record behind them which shows that their personnel has not been wanting in initiative or in ability or in inventive talent. I think I can say with confidence to you, not only as members of an interested industry and as the guests of its members, but as taxpayers of the United States, that the work that has been done on the development of aircraft metal structures here in Philadelphia and in other laboratories and shops has returned full value for every dollar expended, and certainly we have no idea of failing at any time to give the budget and the taxpayers who make the budget possible full value for every dollar received.

If I were to take any one of you individually and go into details and lay facts and figures and records before you, I am very sure that I could satisfy you individually and collectively of that. We have laid out this year about two million dollars on all the experimental work, of which this forms only one part. I wish, and I think that you, if I could take much more time to talk to any of you individually, would agree with me, that we might be in a position not only to carry on this work but to convince you all that we can continue to give full value, not only for what



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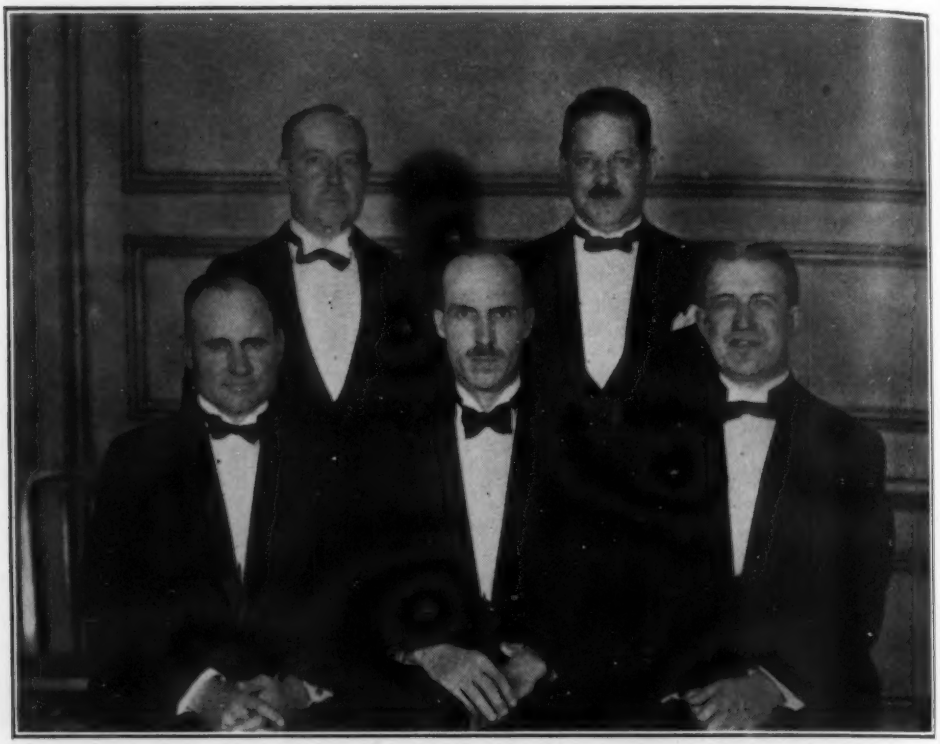


J. M. WATSON, W. H. EISENMAN
DR. ZAY JEFFRIES, J. F. HARPER AND F. G. HUGHES

we have now but for all the money that the Congress of the United States may become convinced that it is advisable or safe or wise to turn over for studies by the government, working ever in cooperation with and ever in full dependence upon the laboratories which are represented by so many of you here this evening.

The next number on the program was a talk by Mr. Douglas Mulloch, who spoke in a more or less humorous vein upon current events. At the close of Mr. Mulloch's talk the toastmaster adjourned the meeting.

Friday, October 12

The ninth technical session convened at 10:00 A. M., in the ballroom of Benjamin Franklin Hotel and was called to order by Professor Bradley Stoughton. E. F. Cone served as vice-chairman. Six papers were scheduled for presentation at this meeting as follows:

10:00—10:30 A. M.—*Metallurgical Problems of Transmission Gearing*—Ernest F. Davis, Warner Gear Company, Muncie, Ind.

10:30—11:00 A. M.—*Decarburization of High Carbon Steel in Reducing Atmospheres*—J. J. Curran and J. H. G. Williams, Henry Souther Engineering Co., Hartford, Conn.

11:00—11:25 A. M.—*Service Annealing of Sling and Crane Chains*—W. J. Merten, Westinghouse Electric and Manufacturing Co., East Pittsburgh.

11:25—12:00 A. M.—*High Carbon, High Chromium Steels*—J. P. Gill, Vanadium Alloys Steel Co., Latrobe, Pa.

12:00—12:30 P. M.—*Steel Failures in Aircraft*—F. T. Sisco, Wright Field, Dayton, Ohio.

On the Equilibrium Diagram of the Iron-Molybdenum System—Takeshi Takei and Takejiro Murakami, Tohoku Imperial University, Sendai, Japan. (By Title.)

The discussion which followed each paper will be published later in TRANSACTIONS.

The tenth and final technical session of the convention was held in the assembly room of the Commercial Museum and was presided over by Professor W. Trinks, as chairman, who opened the meeting at 2:30 o'clock. Four papers were presented, each by the respective author. The papers presented are as follows:

2:30— 3:00 P. M.—*Effect of Furnace Atmospheres on Steels*—R. G. Guthrie, Peoples Gas Light and Coke Co., Chicago.

3:00— 3:30 P. M.—*Progress Made in the Use of Electric Furnaces for Heat Treating*—A. N. Otis, General Electric Company, Schenectady, N. Y.

3:30— 4:00 P. M.—*A New Method for Heat Treating High Speed Steel*—Horace C. Knerr, Consulting Metallurgist, Philadelphia.

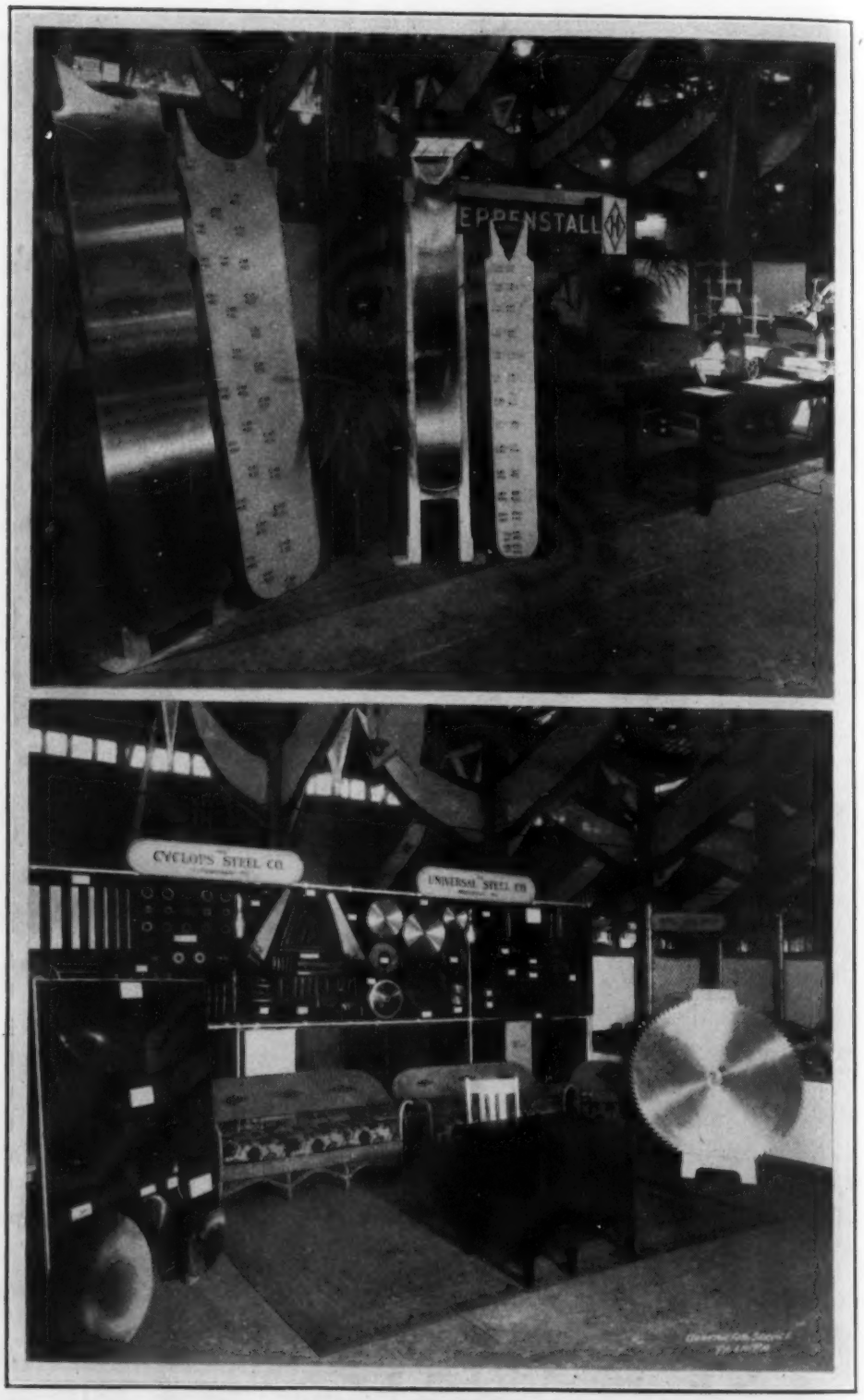
4:00— 4:30 P. M.—*Heating High Speed Steel to 2400 Degrees Fahr. in Molten Lead*—Wilbur C. Searle, Leland Gifford Company, Putnam, Conn.

The subject of fuels and furnaces being of much interest to the membership of the society, a large number of members were in attendance at this meeting, and much valuable and interesting discussion, both written and oral, was presented. The meeting adjourned at 5:00 P. M.

PLANT INSPECTION

An interesting program of plant inspection had been provided by the committee on arrangements and the following plants were open to the members of the American Society for Steel Treating, the Institute of Metals and the American Welding Society during the week. The program for plant inspection was scheduled for the most part in the morning although some of the plants were open to the members in the afternoon, by special appointment. The plants opened for inspection are as follows:

Riehle Brothers Testing Machine Company, Curtis Publishing Company, Leeds and Northrup Company, Temple University,



VIEWS OF THE EXPOSITION

Westinghouse Electric and Manufacturing Company, Victor Talking Machine Company, Autocar Company, Brown Instrument Company, Tinius Olsen Testing Machine Company, U. S. Navy Yard, William Sellers and Company, Inc., Bethlehem Steel Company, Inc., Ajax Electrothermic Corporation, Carpenter Steel Company.

Ladies' Entertainment

Somewhat in excess of two hundred visiting ladies and their guests were entertained with interesting automobile tours around the city of Philadelphia, bridge parties, luncheon parties and shopping tours.

American Welding Society

The American Welding Society meeting simultaneously with the American Society for Steel Treating, held their technical sessions in both the Bellevue-Stratford Hotel in the morning and at the Commercial Museum in the afternoon. A very interesting group of papers were presented at the various sessions, titles and authors of which are published herewith:

Welding in Heating, Ventilating and Plumbing Industry—R. A. Jack, Domestic Engineering.
Oxyacetylene Cutting in the Structural Field—H. E. Rockefeller, Linde Air Products Co.
Welds at Elevated Temperatures—Professor C. Moser, Leland Stanford University.
Welding in the Automobile Industry—J. W. Meadowcroft, Assistant Works Manager, Edward G. Budd Mfg. Co.
Running a Successful Job Welding Plant—J. S. Oechsle, President, Metalweld, Inc.
Formula for Computing Design Stresses for Pressure Vessels—S. W. Miller, Union Carbide and Carbon Research Laboratories.
Design of Welded Structures—F. P. McKibben, Consulting Engineer, General Electric Company.
Erecting a Building by Welding—J. F. Lincoln, Lincoln Electric Co.
Testing Joints for Aircraft Structures Prepared under Procedure Specifications—H. L. Whittemore, Bureau of Standards, Washington, D. C., and H. H. Moss, Linde Air Products Company.
Special film on *Studies of the Metal Arc*—Dr. Karl Bung, German Engineer.
Design of Machinery Parts by Use of Welding of Steel Shapes—Messrs. Hague, Marthens and Brinton, Westinghouse Electric and Mfg. Co.

We are indeed glad to know that the American Welding Society will again join with the American Society for Steel Treating during National Metal Week, to be held in Cleveland, September 9, 1929.

Institute of Metals Division

The Institute of Metals Division of the American Institute

of Mining and Metallurgical Engineers held their fall meeting concurrently with the American Society for Steel Treating. Their headquarters were in the Benjamin Franklin Hotel and the technical sessions were held in the Benjamin Franklin Hotel and the Commercial Museum. The program of the Institute of Metals was as follows:

Less Common Elements in the Electrical Industry—T. S. Fuller.
Gases in Casting Copper—O. W. Ellis.
Diffusion of Zinc Into Copper—S. L. Hoyt.
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On Wednesday evening the Institute held its annual fall meeting banquet which was attended by something over one hundred members and guests. After a short business meeting, F. M. Beckett, vice-president of the Union Carbide and Carbon Research Laboratories, Inc., presented a very interesting paper entitled, "Chromium Alloys." We are indeed glad to announce that the Institute of Metals Division will again join with the American Society for Steel Treating in Cleveland the week of September 9, 1929, in celebration of National Metal Week.

TUNGSTEN CARBIDE—A NEW TOOL MATERIAL

By Samuel L. Hoyt

Abstract

The use of tungsten carbide as a tool material is described. In tool form it has a Brinell number of over 2000 with half the strength of high speed steel and is capable of scratching sapphire. Tests on machining quenched high speed steel, glass, hard porcelain, Hadfield's manganese steel and abrasive compounds are described. On cast iron and steel the carbide tools are shown to be greatly superior to high speed steel and capable of sustaining cutting at speeds which are several times that commonly used. Experience gained in production at the General Electric Company shows that these new tools rapidly attain great industrial importance and that they are indispensable in many lines of work. A number of these applications are described to show the type of performance which has been obtained. In general, the paper gives an account of the first marked improvement in cutting tools since the introduction of high speed steel by Taylor and White.

IT HAS long been known that tungsten carbide is a hard material; and, since this great hardness was first recognized, many attempts have been made to utilize it commercially. The carbide, however, is too weak and porous for most industrial applications of hard materials, and this accounts for the efforts which have been made to increase its strength. Obviously this strengthening must not be accomplished at too great a sacrifice in hardness.

German investigators have been particularly active in this field, as shown by the various German patents covering tungsten carbide. One of their important developments, (a contribution of the incandescent lamp industry) is the tungsten carbide and cobalt combination, represented by the "Hartmetall" of the Osram Co. By means of cobalt, tungsten carbide is made about half as strong as high speed steel, while retaining sapphire-scratching hardness.

A paper presented before the tenth annual convention of the society, Philadelphia, October 8 to 12, 1928. The author, Dr. S. L. Hoyt, a member of the society, is connected with the research laboratories of the General Electric Co., Schenectady, N. Y. Manuscript received July 9, 1928.

In the writer's opinion, great credit is due the inventors of this carbide tool material. These carbide tool materials[1] seem destined to play a dominant part in the industrial life of the future. Various forms of carbide tool materials have been studied by the General Electric Co., both in its research laboratory and in its shops, and it is the experience thus gained which will be described in this paper.

The density of this material runs 14 grams per cubic centimeter and above, depending on the amount of cobalt used. This characterizes it as a heavy metal, almost of the tungsten class. It does not tarnish and, when ground, resembles metals of the steel class in appearance. It resists chemical attack remarkably well and is a pleasing and satisfactory material for use in the arts.

Its hardness can be given in a number of ways. Sapphire is the mineral which comes next below the diamond in hardness. This new material is capable of producing a well-defined scratch in the natural sapphire. When it is borne in mind that the sapphire has an "absolute hardness" of 1150 kilograms per square millimeter, and that a mineral which is as hard as feldspar has an "absolute hardness" of 300, the hardness of this new material receives new significance.

A sample specimen ground to an edge of about 90 degrees is capable of cutting a rather deep, narrow, groove in an alundum wheel without suffering much loss itself; whereas our ordinary tool materials are worn away by the alundum wheel. This behavior on the alundum wheel gives a good idea of the hardness of the material. In fact, even the manner in which a sample scratches a plate of glass serves as a crude test. However, a quantitative, or at least a numerical, expression of the hardness is much more illuminating, and we shall turn to the more formal methods of hardness testing.

Hardness Testing

Metallurgists will be more interested in Brinell or Rockwell tests; and, in our work, we have come to use the Rockwell test almost exclusively to get the correct evaluation of the hardness. Obviously it is not possible to secure the Brinell number in the

[1]The General Electric Co. has adopted "Carboloy" as its trade name for materials of this type.

usual way. For the sake of obtaining quantitative values of the hardness of our samples, and for comparing different materials and treatments, we find the actual unit load supported by the sample during the Rockwell test. This gives a load in kilograms per square millimeter, and it is so closely like the Brinell number in the higher ranges (within 100 to 200 points) that its designation as the Brinell number of this hard tool material seems justified.

In the earlier tests we used the 150-kilogram load with the diamond penetrator and recorded hardness numbers of around 70 on the "C" scale. This load caused the point of the diamond to wear and crumble in too short a time and we have since changed to the "no load" scale, which simply means that no weight is put on the lever arm. The hardness numbers are read on the "C" scale and have come to be known as the Rockwell "A" numbers. To get the unit load on the sample, it was necessary to measure the actual load for the "no load" loading. By making impressions in a sample of hard steel with 150 and 100 kilograms and with "no load" and then measuring the three impression diameters with an accurate comparator, we found this load to be 64 kilograms for our machine by utilizing the principles of Meyer's analysis.[2] The load for our modified test, having been determined, it is then possible to calculate the unit loads for different Rockwell "C" scale readings, or Rockwell "A" numbers. In practice the "no load" hardness numbers are converted into Brinell numbers, when desired, by the relationship given in Fig. 1. The "A" readings obtained on one sample do not differ by much more than $\pm$ 0.5, while the readings of different diamonds may differ from each other by a little more than this as an average maximum. It is not likely that the designation of hardness numbers secured in this way as Brinell numbers will be misleading; and their use brings out differences in hardness much better than the Rockwell numbers do. Certainly nobody accustomed to measuring penetration hardness will be misled thereby. In practice we measure the "no load" Rockwell hardness on the "C" scale and use the numbers so obtained without converting them into Brinell numbers.

We may now compare the penetration hardness of different

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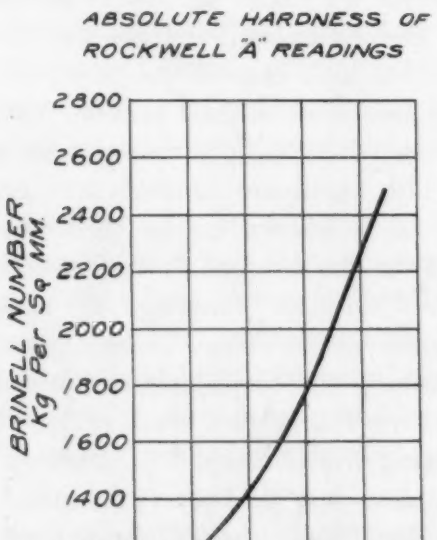
[2] S. L. Hoyt, "Ball Indentation Hardness Test," TRANSACTIONS, American Society for Steel Treating, Vol. VI, 1924, page 396.

materials on a rational basis. O'Neil[3] has shown that the Brinell number of the hardest steel may be taken as about 1000, using a diamond ball point as the penetrator. Common hardened tool steel probably runs closer to 850 as a maximum. The Brinell number of the original German material runs from 1250 to 1400, so that it represents a material increase over the hardest steel. This new alloy runs from 2100 to 2500. The Rockwell "A" numbers for these two materials run 85 to 87 for the German and 90.5 to 91.5



Relationship of Rockwell "A" Numbers to Brinell Hardness Numbers.

for the new material. An interesting check on the relative hardness is secured by comparing the size of the two impressions made, even with the unaided eye. To those who might wish to know the ordinary Rockwell "C" number, the only information that can be given at present is that the German material runs around 70, while the super hard carbide has been found in a few trials to run 75 and above. The wear and tear on diamond points is too great for testing with the 150-kilogram load, but, of course, the sensitivity is reduced by going to the "no load" reading.

Inasmuch as the strengthening of tungsten carbide has been the feature which has given these materials promise of industrial use, this property has more than common interest. D'Arcambal

[3]H. O'Neil, Iron and Steel Institute, Carnegie Scholarship Memoirs, Vol. 15, 1926, page 233.

has shown that quenched and tempered high speed steel has a modulus of rupture in a transverse or cross-bending test of around 425,000 pounds per square inch.[4] Similar tests have been run on tungsten carbide tool material at our laboratory, using a section, one quarter of an inch square with supports one inch and a half apart. The German material is found to run around 225,000, while our material runs around 250,000 to 275,000 pounds per square inch. We have not found it feasible to get a figure for the carbide without cobalt to compare with these figures. It is not likely that a good figure could be obtained, but we may safely say that the pure carbide would come under 50,000. Our experience indicates that such a material would be very weak.

These figures show that tungsten carbide has had its strength increased by the addition of cobalt to somewhat over half that of high speed steel. Viewed in one light, this is to be considered as a very substantial achievement, but this strength must also be regarded as a factor which places a definite limitation on the use of tungsten carbide in commercial practice.

Toughness

Another important property of a material of this type may be called "toughness" (the ability of a material to stand up under stresses or impacts imposed on relatively small areas). A weak, or fragile, material would chip and flake off, but a tough one would be able to stand stresses of this type without injury. This material possesses its share of toughness, since it withstands quite severe blows of a soft peen delivered on the edge of a bar. The blows are delivered in such a way that the edge would crumble if it were weak. A supporting block of copper shows marked indentations as a result of the blows on the material. Inasmuch as the break comes abruptly when the bar does break, the material may be called brittle in that sense. The fracture is of the curved type, while a weaker, or less "tough," material would break straight across. A further demonstration of the strength and toughness of the material is afforded by intermittent cuts on metals.

Thermal, Physical and Chemical Properties

The thermal expansion and thermal conductivity of this new

[4] A. H. D'Arcambal, "Physical Tests on High Speed Steels," Transactions, American Society for Steel Treating, Vol. 2, 1922, page 586.

material is low, but quantitative data will not be given at this time.

The chemical stability of a new material is naturally of considerable interest. The material is probably permanently stable at room temperature and under normal conditions, as we have observed no deterioration in several years. It does not pit or tarnish, and is dissolved in acids only with great difficulty. In many respects it may be expected to show somewhat similar properties and behavior to tungsten. At elevated temperatures the carbon oxidizes, as other tungsten products do when heated in an oxidizing atmosphere. On this account the various operations which are performed on the alloy at high temperatures are carried out under nonoxidizing conditions. The moderate temperatures involved in cutting metals at the speeds which we generally use have not been observed to be harmful. If the speed is raised too high and the abrasion is severe, small particles of carbide may oxidize and shoot off the edge as sparks. Ordinarily, the temperatures involved simply produce temper colors, much the same as they do on high speed steel.

Finally, we have to consider the way in which the material retains its strength and hardness at elevated temperatures. No quantitative test data can be given at this time, but we know from the performance that the German material retains its hardness at a bright red heat to a most remarkable degree. Tools have been observed cutting nickel steel when the point is at this temperature, without showing any ill effects. The new tool material taking the same cut, operates at an appreciably lower temperature.

That such strength, hardness, toughness, and chemical stability just cited, plus the ability to take and keep a cutting edge, must characterize a material of most extraordinary possibilities, as compared to our present tool materials, is self evident to all who are conversant with this field. But we have found that the performance of the material on the lathe and in the shop does actually exceed any reasonable predictions which might be based on a knowledge of these properties. This, in turn, is doubtless due to two circumstances which are highly favorable to this material. The material has no "temper" to be "drawn" by the heat generated, and it is actually much harder than the materials machined, even at elevated temperatures, while steel tools are frequently softer. To get a better understanding of its performance, let us

turn to a review of our experience in several exemplary fields.

Our work at the Research Laboratory has been largely devoted to a study of the performance of this material as a tool material; hence it is to that particular phase of the work that attention will be called.

Use as a Tool Material

One's first experience with a material having such remarkable properties is apt to mislead him into believing that it is capable of almost anything; but it, like other materials, has its breakdown point, first through deficiency in one property, and then in another. Early in the work it became of interest to determine this breakdown point as one means of estimating the economic value of the tools and, particularly, to compare it in this respect to the tool materials with which it would have to compete. In this way we have been led to try it on jobs which are not at all "commercial" and have secured some very valuable information. In this light it may not be amiss to review some of these experiences.

Glass proved to be quite easy to machine, or to cut with screw threads; and we soon found that hard porcelain insulators could be machined on a shaper. It is not often that one wishes to machine anything like hard porcelain; but since discovering that we could do so, we have found that these tools have been used for such work to a limited extent. Hadfield's manganese steel has always belonged to the nonmachinable class; but it was found to yield easily to this new tool material, so easily, in fact, that it would seem that the operation could be developed commercially. For a check on the tungsten carbide material tests, we then tried a standard steel tool on the same material, and found that it lost its edge almost at once, as was to be expected. Since then we have found these carbide tools to be of great assistance in handling many of these hard, tough, and nonmachinable steels. At the Research Laboratory we have occasion to prepare and test many different alloy compositions, and frequently find that it is only with these tools that such alloys can be shaped or surfaced. This experience suggests that steels with higher alloy contents than are now commercially machinable will some day be brought into the machinable class. So far this work has consisted simply in doing jobs which could not ordinarily be done.

At one time we attempted to machine a block of quenched

high speed steel on the shaper. This attempt appeared to be the height of folly, but at least we satisfied our curiosity as to our ability to take a cut on such a hard, tough, material. In that we were successful; but the tool performance was not at all satisfactory, for the edge crumbled. The same was found to be the case on several attempts to machine alloys of the cobalt-chromium type. If one were obliged to machine these alloys, he would be fortunate to have tools of the tungsten carbide type at hand; but the grief involved in tool breakage would be uncommonly great for ordinary machine shop practice.

A complete knowledge of the essential properties of this new material and a correct understanding of the requirements of a particular service would enable us to predict the behavior of it in that service. Of course our knowledge is not that complete, but we probably do know enough to enable us to select the most promising fields. Thus we should expect the peculiar virtues of this material to be most prominent in the field of weak or low tensile materials, which are also uncommonly abrasive to our present tools. Fortunately, for our experimental purposes the electrical industry furnishes a goodly number of such materials which must be machined in daily production. Without attempting to observe any particular order, our experience with a number of these will be given.

Performance in Service

In the production of fused quartz, it has been found advantageous to use molds of carbon—the hard abrasive variety. A considerable amount of experimenting had shown that even the best tool steel lost its cutting edge and began cutting a taper, soon after starting a cut on carbon. The difficulty involved in machining a hollow cylinder of carbon may be easily imagined. On putting tungsten carbide-cobalt tools on this job we found that we could take the entire cut without tool wear, and therefore without tapering. This statement means, of course, that the cut was parallel within the tolerance allowed.

Genelite is composed of copper, tin, and carbon. It is so soft, in one sense, that it can be whittled with a knife blade very easily, but it is also so abrasive that a lathe operation dulls a steel tool almost at once. A cut on a small cylinder of only a few inches in length is always on a taper. This again demonstrates the extreme

abrasion which may be involved in the machining of carbon. Tungsten carbide tools were found to machine Genelite with no difficulty and accurate tests of the cuts made showed that they were not tapered. A careful inspection of the cutting edge confirmed this observation by showing that no wear had occurred.

Commutators of electric motors are composed of alternate layers of copper and mica. The bearing surface of these has to be machined after assembly on the shaft. The mica is quite abrasive and has always presented a problem to the machine shop, because the operation is one which must be carried out accurately. With high speed steel a sacrifice must be made on this job, either in speed, or in the finish of the surface; whereas the carbide tools cut through the mica without undue wear and give a smooth finish to the commutator.

Mycalex is an insulating material of such excellent properties that there is considerable demand for it in the electrical industry, is spite of the extreme difficulty with which it can be shaped or machined. It is composed of fine mica particles and lead borate, the latter acting as a bond for the mica. Ordinary tool materials are worn away at once on this material so quickly that it would be difficult to give quantitative data on their performance. The effect and noise produced brings to one's mind a picture of an attempt to machine a grinding wheel. Tungsten carbide tools, on the other hand, are capable of machining Mycalex commercially, and we have observed tools cutting over 1000 feet linearly before losing their edge. Other molded compounds come under the same category and need not be considered separately.

Materials like Bakelite and hard rubber are very abrasive when machined at high speeds. One of our operators demonstrated to the writer that even though he had made his steel tool as hard as "fire and water could make it" the cutting edge was rounded off very soon on hard rubber. Although the ease with which this machining was done made this result surprising, the evidence was very clear. Carbide tools keep their cutting edge very well on hard rubber, and have been very satisfactorily used.

Bakelite offers somewhat similar problems and, on account of the necessity of machining Bakelite at high speed, diamond tools have been commonly used. This was the only tool material which had been found to stand up at the speeds used, but the diamonds

possessed one disadvantage which was overcome by substituting this new material. If the part machined contained a metal insert, a special operation was required to recess this part below the cut of the diamond, for if the diamond were to hit the metal at high speed, it would break off at once. Here the tungsten carbide tool necessitates no such special operation because it cuts both the Bakelite and the metal insert.

On a somewhat similar operation we compared tungsten carbide tools with a well-known special alloy cutting tool which had given the best performance on this operation up till then. Three tools were used on this job on two different heads, finishing three faces on the part. The tools of the special alloy required redressing every 150 parts machined, on the average, before the tools became dull enough to require sharpening. Carbide tools were substituted under the same operating conditions, and finished 11,000 parts before they became dull enough to be redressed.

In the "low tensile" field the durability of the tungsten carbide tools has been found to be of the order of 25 to 75 times that of high speed tools, or so great that the simplest kind of a test demonstrates the vast superiority of the carbide tool. Here the tool pressure is always light, the cuts are small, and the cutting speeds are high. Resistance to either wear or "burning" is the chief requirement of the tool. Coming to cast iron we find that the cutting conditions are apt to be radically different. The parts are frequently large, the cutting speeds are much lower, the cuts are heavier, and the tool pressures are greater. The heavier pressures are due in part to the higher unit pressures exerted by the iron, but more particularly to the larger cuts. In this way the tool pressure becomes a more prominent factor in tool performance, but our experience shows that cast iron comes well within the field which can be handled by this new material.

Machining Cast Iron

The machining of cast iron by carbide tools offers a variety of problems so that it will be well to consider the subject from several different points of view.

One of the most difficult jobs to do on cast iron with the usual tools is that of removing the surface layer, particularly if the surface contains sand. This is due to the fact that the chilled iron

and sand are harder than the tool used to cut them. As has been pointed out, this material is harder than sand and chilled iron, so that castings which would take the edge off high speed steel almost at once can be handled with but little difficulty. In fact, we commonly use about the same speeds and feeds on these cuts that are used on the sub-surface cuts. Even cuts which travel in and out of the surface layer cause no particular trouble, and such cuts are recognized as being the most abrasive on the tool.

A somewhat similar problem is presented by "hard" castings. If a machine shop is accustomed to machining castings of some particular grade, a run of castings which is appreciably harder is certain to increase the machining costs whether the increase be due to annealing, to a lower production rate, or to scrapped castings and lost time. These castings may be, and quite likely are, of a better grade than the softer castings with which the shop is accustomed to deal. From that point of view it is unfortunate that they cannot be satisfactorily and economically handled. Tungsten carbide tools machine these "hard" castings with ease, and it has been our experience that a run of such castings will go through the machine shop without disturbing the practice in any way. Naturally, the tool life is diminished according to the increased abrasion of the harder iron, but the tool life of this new material on cast iron is normally so great, that the decrease involved is not a serious matter. Furthermore, it is not an uncommon occurrence that the use of carbide tools obviates the necessity of scrapping a large casting on which considerable work has been done. The cost of the casting may be many times as much as that of the tools used. The improvement in shop practice and morale can be easily pictured by those who have this type of work under their supervision.

In the manufacture of armature spiders for electric motors it is necessary to take a cut over the ribs to true up the spider. This cut is an intermittent cut, and has given us an excellent opportunity to test the behavior of tungsten carbide tools under impact. The impact on the carbide tool is generally greater than on the high speed tool on account of the higher speeds used with the former; but, in spite of this factor, we find that these tools stand up very satisfactorily under this service.

Not much can be said at this time on the use of this material

as a finishing tool on cast iron for, obviously, this will require quite a special study. In tests, the author has observed that a speed of 300 feet per minute is sufficiently high to take the edge off high speed steel and other tools almost at once. In fact, in one such test the cast iron acted more like a grinding wheel and wore off the tool as rapidly as it was fed into the work. The carbide tool used in a parallel test was ground to a rather keen edge and was able to take a light cut for over a foot in length along a block about six inches in diameter with no appreciable wear on the edge. This test suggested that cast iron is more abrasive at high speeds than steel is, but we are not sure this is correct.

As the hardness of the cast iron decreases, or as the grain becomes more and more open, the abrasion on the tool becomes less and heavier cuts and higher speeds can be used. Abrasion resistance becomes less of a factor in tool performance, and the strength of the tool, particularly in the case of tungsten carbide, enters more prominently. In practice this is readily taken care of by being sure that a tool of sufficient size is used for the cut taken, for the unit pressure in machining cast iron is not large. Quite naturally this type of iron is most commonly met with in large castings. Here the speeds which can be used are correspondingly small, because large masses of metal are not moved as rapidly as small masses, and the necessity of reducing the time of machining requires the use of heavy cuts. Even this cursory discussion, which cannot possibly depict the situation fully, is probably sufficient to show that the advantage this material possesses over high speed steel is greatest for small castings, and hard iron, and that it decreases as the size of the casting increases and the hardness of the iron decreases.

Our work on cast iron has shown clearly that tungsten carbide-cobalt can machine harder and denser grades than can be economically handled by high speed steel tools. It is logical to assume that the iron is made soft enough to avoid running up machining costs inordinately high, and that the most important factor in the situation is the cutting efficiency of the tool material. It is also logical to assume that practice aims at producing iron which, on the average, is well below the grade which begins to give trouble. Such being the case, an economic advantage is bound to follow the

introduction of a cutting tool whose cutting efficiency is well above that of our present tool materials.

Coming to steel, we enter what is probably at once the most important and the most difficult field for this new tool material. The difficulties arise mainly from the high tool pressure involved. Even so, our early tests on annealed tool steel, mild and medium carbon steel and wrought iron led us to expect that it would show equally as spectacular performance here as in the work already mentioned. These expectations have been adequately realized in tests such as the following.

At one time we ran a series of tests on a nickel steel test log, the Taylor speed of which was about 54 feet per minute under our standard conditions for testing high speed steel. We soon found that if we were to get any adequate estimate of the life of carbide tools on this log, we would have to increase the speed to around 200 feet per minute. This threw us quite out of the range of speeds used with high speed steel, and we decided to run the high speed steel under the conditions set for the carbide tools. The calculated tool life came under 30 seconds, while the tool on test failed in 16 seconds, having had its edge burnt off almost at once. The tungsten carbide tool was then set up in the same way, and after running for one hour, the test was arbitrarily stopped for the tool was still cutting and capable of cutting for a much longer period. The difficulties involved in determining the tool life of these carbide tools may well be imagined from the results of this test. In fact, they are so great that we do not commonly run the tools to failure but stop the test at some predetermined point and inspect the tool edge to see how it has worn. One of our test logs is a chromium-nickel steel with a Brinell hardness number of just over 250. With a cut of $\frac{3}{8}$ inch and feed of $\frac{1}{8}$ inch we find that good high speed tools fail at 35 feet per minute in about 6 to 8 minutes. We run the carbide tools with the same cut and feed, but at 70 feet per minute, and stop the test at 10 minutes. The tools show only slight wear at that point.

In this work on steel we have carried the thought in mind that the principal factor limiting the performance of carbide tools is the strength of the material. This is predicated on the use of the proper tool shape, cutting angles, sizes of tool, etc. To test out this viewpoint we ran a series of tests to determine the proper ratio

between the chip cross section and tool section. These tests showed that normal service may be expected if the chip area is of the order of 1 per cent of the tool area. Expressed otherwise, we may expect good service from tungsten carbide tools on steel if a sufficiently large tool be used for the job at hand, provided that the feed be not too great. This, in turn, will vary with the steel machined, so that definite recommendations could be given only for specific cases.

This account of this tungsten carbide-cobalt alloy has shown that the use of tungsten carbide as a tool material has increased the cutting ability of the tool by a whole order of magnitude. This is the first time this has been done since the introduction of high speed steel by Taylor and White. Granting this improvement in cutting ability, the extent of the use of tungsten carbide will depend largely on the cost of operating with such tools and their output, as compared to that of high speed steel. The ingredients of carbide alloy and the process of making it are expensive so that we may safely say that it will cost more than high speed steel; but we have found by an extended study of many fields that the improved performance of such tools more than offsets their greater cost. In these cases our shops find that they cannot afford, now, to operate without the carbide tools. If the present limited experience with this material does not mislead, because of its very sensational properties and behavior, further possibilities of development are both manifold and attractive.

The research and development work on this new alloy has been carried out as a large scale investigation, in which members of the staff of the Research Laboratory and of other departments of the General Electric Company have participated.

DISCUSSION

Written Discussion: By Philip M. McKenna, research metallurgist, Vanadium Alloy Steel Co., Latrobe, Pa.

It would be interesting to know the volume occupied by the various constituents with a view to comparing their atomic concentrations with those of other hard substances. In general the harder substances seem to have greater atomic concentration as for example:

The idea of the measure of hardness being the specific gravity divided by the atomic weight is an old one having been stated by Bottone (Chem. News, Vol. 28, p. 142, 1873).

Discrepancies from the rule are accounted for by the subtraction of a factor for electrical conductivity,* better conductors being softer. Now the question I should like to ask Dr. Hoyt is, what is his understanding of the deviation of tungsten carbide from the series, it having a factor of atomic concentration of only 0.160 or 0.127 (WC or W_2C) while Al_2O_3 is

	Sp. G.	Mean At. Wt.	At. Conc'n.	Hardness
Diamond	3.51	12	0.293	10.0 Moh's.
WC	15.7	98	0.160	
W_2C	16.06	126.5	0.127	
Boron (Adamantine) ..	2.68	11	0.244	nearly diamond
Al_2O_3	3.96	20.4	0.194	9.0 Moh's.
SiC	3.23	20	0.167	9.0 Moh's.
Quartz	2.65	20	0.132	6.5-7 Moh's.
Fe (gamma)	7.8	55.84	0.142	
Fe (alpha)	7.9	55.84	0.141	
Cu	8.9	63.57	0.14	
Sn	5.8	118.7	0.0487	
Pb	11.4	207.2	0.0553	

0.194 and SiC is 0.167, nevertheless the new material scratches sapphire.

Does Dr. Hoyt subscribe to the views of Arne Westgren and Gosta Phragmen (Z. Anorg. Chem. 1926, 156 pp. 27-36) that the atoms of carbon in the system W-C are like solid solutions of carbon in gamma iron, or like carbon in manganese "sprung" between the heavier atoms. Assuming the usual densities of tungsten and cobalt, what is the computed value of density of carbon in the new material? Dr. Hoyt's paper gives a density of 14, but this is presumably not intended to be a close figure. Does the carbon in the new material have a density approaching that of diamond, assuming the usual figures for W and Co?

Written Discussion: By W. A. Wissler, Union Carbide and Carbon Research Laboratories, Inc.

I believe that any discussion of the development of cutting tools is incomplete unless the discoveries of both Taylor and White, and Elwood Haynes are included.

Mr. Haynes, who invented and patented the Stellite alloys, should be credited with having made an advance in cutting tool performance that was a greater improvement over high speed steel than high speed steel was over carbon tool steel, when machining in general is considered. Mr. Haynes was the first man to discover the value of cobalt as a matrix for chromium, tungsten, and carbon, and to show that its use instead of iron resulted in a marvelous increase in the degree of red hardness possessed by the tool. This step was important in another way, in that it demonstrated for the first time that non-ferrous alloys could be used for machining iron and steel.

Tools of the tungsten carbide type will do many things that cannot be done by other tools and they seem to be especially fitted for certain definite types of work, such as turning such materials as glass, bakelite,

*Ernst Friederich, Fortschritte, Chem. Physic, physic chem. 18, 5-44 (1926.)

carbon, porcelain, hardened steel, chilled iron, etc. For these uses they are undoubtedly superior to all other alloys. This type of work, however, constitutes only a small fraction of the machine work done in this country.

In general, the operation of machining may be divided into three classes, depending upon the kind of material being machined or the nature of the work being done. One of these groups includes the work done on cast iron, semi-steel and similar materials. The second group includes machining that is done on steel parts of such size or shape that they may be rigidly held, with the result that the work does not spring or give under the tool. This class constitutes only a relatively small proportion of the steel machining business. The third class comprises production work, typified by the machining operations on crank shafts, cam shafts or similar parts for the automotive industry. Many jobs of this type are done on automatic or semi-automatic machines with multiple tool set-ups, with the result that there is an almost indiscernible but nevertheless constant vibration. This class of work constitutes a large proportion of the steel turning business of the United States.

It has been found that a new tool must be thoroughly tested on each of these types of work to determine its degree of merit on such applications. A tool for machining cast iron must have a high degree of abrasive resistance and may sacrifice a certain amount of strength if its resistance to abrasion can thereby be increased. On the other hand, a tool for machining steel under rigid conditions should have sufficient strength to enable it to stand up against heavier chip pressures, even if a gain in strength is accompanied by a slight decrease in hardness and resistance to wear. The third class of work comprising production steel machining requires a tool having enough edge strength to preserve a keen edge and hold size on a sharp corner in spite of the small and constant vibration that tends to dull the tool. Machining operations, at least on cast iron and similar materials, should undoubtedly be sub-divided into milling, boring and turning, and each of these three sub-divisions should probably be broken down again into continuous and intermittent machining operations, as the character and type of tools required for each type of machining may be quite different. As an example, tougher tools are necessarily required for intermittent cutting than for continuous cutting. These various properties are required in addition to the property of red hardness, which is the essential quality possessed by all good tools and which enables them to operate at high speeds without becoming soft at the high temperatures developed.

It is my opinion that tungsten carbide tools will be more successful in the first two classes than in the third, and I am inclined to doubt that tools of this type will displace high speed steel for production steel turning. Stellite is extremely successful on the first two types of machining operations but its successful applications in production steel turning are much more limited.

While Dr. Hoyt did not go into shop tests in detail and has covered the subject in a general way, I wish to point out that the tests given on cast iron and steel are not conclusive and should be reported in much

greater detail before the reader would be enabled to come to any conclusion as to the relative value of tungsten carbide, Stellite and high speed steel for any particular job.

There are several disadvantages in these tungsten carbide tools at the present time. One of these is the high cost per unit volume as indicated by present market prices. Another is the difficulty of grinding the tools and the resulting tendency on the part of operators to improperly sharpen the worn tools. This will raise the sharpening cost considerably. Tungsten carbide will be used in the form of small tips welded or brazed to steel shanks which will reduce the amount of metal required but will increase the fabricating cost.

Tungsten carbide tools are extremely hard. I have used the Rockwell "no load" scale, calibrated by calculating the leverage of the machine from the actual weights of the 100 and 150 Kg. weights. The machine had a "no load" load of 58.5 Kg. The use of a weight weighing 44.7 grams gave a load of 64 Kg., thus making the machine correspond with that of Dr. Hoyt. With this load the hardness of the German made tungsten carbide was found to be about 87, as Dr. Hoyt has stated.

On the other hand, I have not as yet seen any tungsten carbide tools that were capable of cutting deep grooves in a grinding wheel, if the wheel was running at the proper speed. I have found that such tools apparently grooved the wheel deeply, but an examination of the wheel at rest showed that the grooves were only a few thousandths of an inch deep, and this was accomplished only at the expense of severe wear on the tungsten carbide used. I have had no opportunity of examining the exact material referred to by Dr. Hoyt, but it would seem that the difficulty of grinding an alloy which is capable of cutting grooves in a grinding wheel would severely handicap the tool by the expense of resharpening.

I should like to ask Dr. Hoyt if he has made any red hardness determinations and whether or not he cares to give at this time some idea as to the temperature at which these tools soften. It appears there is some discrepancy between the statement on page 13 that a tool making a cut ⅛ x ⅜ inch was satisfactory, and the statement on page 14 that the area of the tool should be one hundred times that of the chip. This would require a tool having an area of 5 sq. inches, which seems improbable. This point is being raised to clear up a possible error in an admirable paper.

Written Discussion: By Dr. Albert Sauveur, Harvard University, Cambridge, Mass.

Dr. Hoyt must have convinced the most skeptical of us that tungsten carbide makes a marvellous cutting tool and that he is justified in saying that this is the first time since the introduction of high speed steel by Taylor and White that the cutting ability of a tool has been increased by a whole order of magnitude. The author arouses our interest, hence our curiosity, and we are led to ask questions to the point of possibly being indiscreet.

We would like to know the percentages of carbon and of cobalt present

in the alloy and the chemical formulae ascribed to the carbide or carbides, the process of manufacture, the method of grinding the tool, etc. Any information which he cares to give us on these points will be welcome.

Oral Discussion

A. H. D'ARCAMBAL: In Dr. Hoyt's excellent paper he stated that cobalt was added to tungsten carbide. We would be interested in learning the percentage of cobalt that is to be found in this material.

Another question we are interested in is the method used for regrinding these tools.

The tool manufacturers are much interested in learning whether a good finish can be obtained with a tungsten carbide tool. We of course know that a tool made of carbon tool steel gives a better finish than a high speed steel tool. Just what classification would the tungsten carbide material be placed in? Also, how would it compare with Stellite as a finishing tool? The previous speaker compared Stellite with some of the high speed steel and tungsten carbide tools. It would be interesting for Dr. Hoyt to run a transverse test on Stellite to see if that has any more than fifty per cent of the strength of high speed steel properly hardened and tempered.

DR. R. W. WOODWARD: I rather hesitate to make the remarks which I am about to make for fear that they may detract somewhat from the extreme value of this paper, but inasmuch as I feel that a few remarks are in order in regard to the hardness test, I hope that Dr. Hoyt will pardon me for bringing them up at this time.

Dr. Hoyt has used what he has termed the Rockwell "A" scale, and in doing so, has removed the normal weights from the machine and called that the "no-load" weight. Of course, the term "no-load" is rather ambiguous as there of course is an actual weight applied, consisting probably of the weight arm, in his case. By means of Meyer's analysis he has determined that this load was 64 kilograms for his particular machine. I recall that at the last meeting of the American Society for Steel Treating there was a paper presented by a member of the testing materials laboratory of the General Electric Company in which was offered a means of calibrating or measuring the load on the Rockwell hardness tester. I would like to inquire if Dr. Hoyt has checked his machine by that method.

In the early models of the Rockwell hardness tester, although the machine was carefully standardized at the 150-kilogram load and the 100-kilogram load, the no-load, so-called here, was not that carefully standardized and there probably was considerable variation in the different machines. At the present time and for a considerable time this so-called no-load reading has been carefully standardized at 60 kilograms, so that every machine can be used interchangeably at that load.

On the fourth page in the paper Dr. Hoyt gives a conversion to Brinell numbers by means of a computation from his Rockwell "A" numbers. Presumably, this curve is computed on the basis of his 64-kilogram load. I would like to issue a word of warning that this conversion probably would not be applicable for other machines, particularly those that have the standard load of 60 kilograms.

On the other hand, I hardly see the necessity of converting these readings to Brinell numbers, since the conversion at this range is practically a straight line and we are simply increasing the order of magnitude of the numbers which we use without in any way increasing the sensitivity of the hardness readings.

O. W. BOSTON: Some of the points I had in mind to make have already been made. It does seem to me that the members of the Society are extremely fortunate in having the information as presented in this paper made available to them, as certainly tungsten carbide is going to play a very important part in some of the manufacturing of the future.

I have two or three comments and questions I would like to make, one of which refers to the tenth page of the paper just below the middle of the page, at the beginning of the second paragraph, in which it is stated that "In the 'low tensile' strength field the durability of the tungsten carbide tools has been found to be of the order of 25 to 75 times that of high speed tools." I should like to ask if that tensile strength includes the cast irons. Presumably not, because in the latter part of that paragraph cast iron is again referred to specifically, so presumably "low tensile strength materials" covers aluminum, babbitt, the bronzes, and so on.

In the latter part of the same paragraph reference is made to the higher unit pressures exerted by the iron. That seems to me to be an error, in that experiments have shown that cast iron produces a lower unit pressure per square inch of chip cross-sectional area than the steels. This seems to be corrected, at least is reported favorably, in the middle of the following page.

Another point that it seems to me could have been elaborated on perhaps a little more is the method of finishing the tools made of tungsten carbide and the shapes and angles employed in the cutting. We know, for instance, that Stellite must be treated differently as to its geometrical shape than high speed steel, and it would be interesting to know or to have a little more information as to the general use of tungsten carbide.

Unfortunately, in some of the tests which have been given to show the comparative tool life of tungsten carbide with high speed steel, very little information of a specific nature has been given. For instance, nothing has been given as to the relative costs. I might also suggest that Stellite be added to the three tool materials, tungsten carbide and high speed steel, to make the analysis a little more complete.

Furthermore, in these tests the speeds, feeds, depth of cut, that is, as used on different materials, has not been given. That, I think, would give all of us a more comprehensive understanding of the application of the tungsten carbide-cobalt tools. Undoubtedly, much of this material that has been commented on here as being lacking in the paper will be made available as the use of tungsten carbide becomes more general.

R. F. COHN: I had the opportunity last winter in Germany of visiting factories where these materials are being used. In this connection, I would like to call to your attention the fact that this material abroad has progressed beyond the experimental stage as far as its use in dies is concerned. You are very much interested, as I am also, in its use as a material in tools. I believe that the field of dies might have received a little more attention,

inasmuch as it has been developed to a very considerable extent in this field.

I have one question that I would like to ask Dr. Hoyt. I noticed that in Germany these materials were being made in an electric furnace and that in the paper presented this morning the non-oxidizing atmosphere, I believe, of hydrogen is mentioned. May I ask if there is an actual difference in the resulting material which may be attributed to the type of heating?

J. L. Cox: What I wanted to say is not especially pertinent to the paper on tungsten carbide, but I twice today heard the invention of high speed steel ascribed to Messrs. Taylor and White. Now, I have not the slightest wish to detract from the very great credit due to those two gentlemen for what they have done, but I think it is fair to state most emphatically that the invention was not made by Taylor and White, it was made by Mr. H. A. Brustlein and the steel was first produced at the works of Messrs. Jacob Holtzer & Cie. at Unieux, Province of the Loire, France. The steel used by Messrs. Taylor and White for their experiments, certainly at first, was made in Philadelphia following the analysis of samples obtained from France. Later, their steel was melted at Bethlehem but long before their experiments on its heat treatment were begun, the steel was in regular commercial use.

H. J. French: Mr. Chairman, I hesitate to add to Dr. Hoyt's burden of questions, but I would like to ask him whether he can give us any idea as to when we can reasonably expect to be able to get samples of this tungsten carbide tool material of which he speaks, at least for the purpose of throwing further light on the fields of best application. We have heard of tungsten carbide tool material for some time but as far as I have been able to determine, up to this time we are much in the same position as a hungry man who sees a container of food in front of him to which he has no access.

I would like to ask another question, and that is whether Dr. Hoyt's experience with this material would indicate that it is applicable to high speed, fine-finish turning and I have in mind the possibility, at least in some applications, of replacing grinding by very high speed turning, including, of course, the use of cutting compounds.

Then, there is a third question and that has to do with his experience relative to the uniformity of performance which can, at the present stage of development, be produced in these tungsten carbide tools.

W. Trinks: May I ask whether a representative of the Krupp works of Germany was invited to take part in the discussion? Similar to Mr. Cohn, I had the pleasure of seeing demonstrations of tungsten carbide tools at the Krupp Works in Germany this summer. There I was handed a paper in which the increases of speed that could be had with the tungsten carbide tools compared to what they called the best tool steel speeds were given graphically. I have several of these papers at my home, and if there is any advantage in giving them to the Society for what they are worth, I will be very glad to do so. I also have samples of tungsten carbide at home, and if Mr. French wants them, I think I can let him have them also.

In the instructions which the Krupp Company issue, the angles of cutting for different kinds of tools, for planning and for turning are also given. I believe that would answer what Professor Boston wants to have. But I really believe that it would have been very interesting to have heard from the

representatives of that company, because from what I could observe over there, they have done a great deal of development work.

A. H. D'ARCAMBAL: May I ask, Professor Trinks, if the material now being used in Germany has the addition of cobalt, or are they still using the pure tungsten carbide?

W. TRINKS: They have a binder. They just said it was a binder, they did not tell me what it was.

J. L. COX: Dr. Strauss told me it was a cobalt binder.

MR. COHN: May I add to that by saying that I understand that the Krupp material contains a little less cobalt than the material being made in this country. As I understand it—and I believe Dr. Hoyt will be glad to correct me if I am mistaken—this Carboloy, so-called, is obtainable in two distinct grades, one used for cutting purposes, another used for die purposes, and the difference I think lies largely in the percentage of cobalt in the two materials.

CHAIRMAN ALBERT SAUVEUR: I am sure that if there is a representative of the Krupp Works in the room, we will be very glad to hear from him.

DR. S. L. HOYT: I want to say first of all that I appreciate very much the discussion which this paper has aroused and that I hope that the further experience on the part of others with this material will not come as an anti-climax to the interest which is shown here.

A number of questions have been asked regarding cutting angles and depth of cuts and feeds and finishes, etc., which are all very reasonable and logical questions, and in order, but my feeling is that they require special rather than general replies and that a means has been established whereby such specific answers to these questions can be given and I would, therefore, refer those people who have these questions in mind to the Exposition, to the Carboloy Company, to take the matters up with them rather than attempt to reply to such questions here.

To reply to the discussion serially here, the first speaker, Mr. Wissler, of the Union Carbide Company, mentions Stellite. I must say that, naturally, in writing this paper, my interest is largely with tungsten carbide and that I was comparing it in general with other tool materials. Now, high speed steel is undoubtedly the one which has greatest commercial importance at present, and without any view to detracting from the value of Stellite, which the General Electric Company realizes as well as any other large user of tool materials, I just naturally, I believe, avoided making any very specific references to Stellite; and the same would hold for various other tool materials which also have their special fields of application.

He also throws out a word of caution in extending its application and cites the experience which they had with Stellite. The same caution is necessary now that was then, and in that point I fully agree with Mr. Wissler. I am sure that everybody who has so far been associated with the development and use of tungsten carbide tools will feel the same way about it, that there is a decided need for caution in extending its applications; and the field of applications will not broaden over night, it will take a reasonable amount of time and experience to insure getting the proper kind of applica-

tions for any new tool material. So with that portion of Mr. Wissler's discussion I certainly am in thorough agreement.

A number of comments have been made on the Rockwell "A" scale, and possibly I may as well finish that up at once. For some time I rather hesitated testing this material with the Rockwell machine because I was afraid I would break the diamond point and then other folks around the laboratory would be rather out of luck for a while. But finally I decided to test it on the Rockwell machine and did so, but I very soon found that the diamond points were breaking and we subsequently had to overcome that by simply having a supply of diamond points on hand. We then went to a load of 100 kilograms with the diamond point and that helped out some, too, but as soon as we began getting hardness numbers which, on the Rockwell "A" scale, run 90 and above, we found that even a 100-kilogram load broke the diamond point too frequently. So then I took the load off altogether, and that is how I arrived at this no-load loading.

It is true that "no-load" loading is really a misnomer. I would be glad to have somebody suggest a better term for it. By lowering the load on the diamond point, the sensitivity decreases very greatly and I believe that point is brought out by the curve in Fig. 1. For instance, a Rockwell "A" reading of around 86 indicates only one-half the resistance to penetration by the diamond cone as a Rockwell reading of 90.5 does, so the restistance to penetration has jumped 100 per cent but the Rockwell "A" number has jumped only a few points, and it was simply to throw light on that particular situation that I converted the numbers into Brinell numbers and gave this Fig. 1. As a matter of fact, there is no practical reason for making that conversion and in practice we do not, we simply determine the Rockwell "A" number and use that as such.

As for the tests on grooving the wheel, etc., that was described to throw some light on the extreme hardness of this material, and I am sure if any one of you will take a piece of this Carboloy and walk up to an alundum wheel with it and do what I suggest here, you will get the point of the remarks, and I am sure you will be impressed with the hardness of the material, and that is really all I had in mind in pointing that out. It is not a test for hardness, it is just a little stunt that can be done, like scratching a sapphire. Nothing much is gained by scratching a sapphire, except that you find out that the material is very hard.

This suggests to Mr. Wissler's mind the difficulty of grinding, and that, of course, is a point well taken, but we find that wheels of the silicon carbide type have proven to be very satisfactory in grinding tungsten carbide tool materials. These are used in two different grades, coarse and fine, and with suitable precautions, it is a comparatively simple matter to grind and redress tungsten carbide tools.

I might not be entirely correct in this statement, but I rather have a feeling that tungsten carbide will probably be easier to handle than high speed steel.

A. H. D'ARCAMBAL: May I interrupt to ask if the grinding is done dry?

DR. S. L. HOYT: The grinding is done dry, and no water is allowed at all. The pressures are lighter and the grinding is done dry. If you do not

do that, the difference in coefficient of expansion between the tungsten carbide and the steel and the lack of thermal conductivity of the tungsten carbide itself leads to checking.

I have no figures on the red-hardness of this material, but machining a nickel steel log at 200 feet a minute raises the temperature of the cutting edge to a red heat and some of us estimate it a bright red heat. Other than that, I have no figures on it except this, that if you go to a higher temperature, say again, by estimate, around 1100 degrees Cent., the material is very, very soft. For instance, if you bear into an alundum wheel with a piece of tungsten carbide so hard as to raise its temperature up to a white heat, you will see that it grinds away very easily, very quickly. But the useful range of temperature is undoubtedly very high.

His last point is the apparent discrepancy in the chip to tool area. The cut of ⅜ of an inch by ⅛ of an inch was a test cut such as you would be apt to run off on your own test log to see what the tool would do, etc., and is not a cut which would be used in practice. The chip to tool area of one per cent which is mentioned refers rather to practice that you would be apt to set up out in the shop, in production, and I think that takes care of that discrepancy.

Mr. d'Arcambal has asked for the percentage of cobalt. As a matter of fact, the cobalt may be anything up to twenty per cent. The particular point at which you stop depends upon your judgment, or rather, upon the properties secured. As the cobalt content increases, the hardness decreases and the strength increases, so that you stop at the point where you secure, in your judgment, the proper combination of strength, hardness and toughness for your particular job.

A. H. D'ARCAMBAL: Just what form would the cobalt be in, Dr. Hoyt?

DR. S. L. HOYT: Well, it is added as pure cobalt. It undoubtedly changes a little during the treatment, but it is largely pure cobalt, and the percentages normally used run around eight per cent, the lower cobalt for the harder materials, for wire drawing, five to eight per cent; the percentages for tools run over ten per cent. But as soon as you get up too high in cobalt, —you metallurgists will be interested in this,—in spite of the small drop in the Rockwell "A" hardness number, the resistance to abrasion drops off quite rapidly.

The next speaker mentions particularly the Rockwell "A" hardness number, methods of checking the load and so on. I believe I have replied to him sufficiently. If not, I would be glad to reply further. That is what I have said in the paper and what I have already said in reply I believe takes care of that.

Professor Boston asks if cast iron is included in the low tensile materials, and the answer is no. I thought the point was clear enough in the paper, but if it is not, that is it.

That takes care of his next point as to the unit pressure of iron and steel. The unit pressure developed in machining steel is, of course, considerably greater than in machining cast iron, so that I will agree with him thoroughly there. And Professor Boston's other points I believe I have also taken care of by referring to the Carboloy Company.

The next man told of the use of tungsten carbide dies in Europe. They are also used in this country to some extent and I believe their extension to other fields is justified.

He also asks about heating. I said "non-oxidizing atmosphere" in the paper. We actually use a hydrogen atmosphere, but I suppose other atmospheres could be used all right. But we find that hydrogen has many advantages, and at Schenectady we are very accustomed to using hydrogen and it is convenient, it is at hand, and it has been very satisfactory.

Mr. Cox has referred to high speed steel, or the part played by Brustlein in the development of high speed steel. Personally, I am very pleased to hear his comments on that point. I have never had occasion to go into the history or to learn the true history of the development of high speed steel and I simply have taken what I have commonly understood was the case. I am very grateful to Mr. Cox for pointing this out.

Mr. French has asked for samples. I think they are going to be available right away.

He also asks as to uniformity. We have found in the last year or two that the uniformity of our tungsten carbide tools has been very excellent. That is naturally a very important point in commercial practice and the development work which was responsible for that was very gratifying.

Mr. French also asks as to the possibilities of using it for high speed turning. Just let me give one example there. One job that we studied a little was turning fiber bushings. It was desired to have a smooth finish on the bushings, but the speed corresponding to the economical tool life was below the speed which gave the best finish, so we put tungsten carbide tools on the job, raised the speed to that which gave a good finish, and secured not only the improvements of finish but also the increased production.

Now, that would hold true, I should think, on materials of the fiber class. On other types of work I think the most of that is still to be worked out and I would have to ask Mr. French to await future developments.

Professor Sauveur has asked a number of questions about the process of making these materials, percentages of cobalt, etc. We prepare tungsten carbide first in finely granular form, and the cobalt the same way. When the two have been prepared in finely divided form, they are then properly mixed so as to secure a uniform composition and are then put through the regular process for handling tungsten, pressed up into shape, and sintered by heating in a hydrogen furnace at a proper sintering temperature, 1350 to 1375 degrees Cent., which converts them into a permanent form.

The process I have just described is only one process for making this material, there are others which we have worked upon and which give promise of improving properties in one direction or another.

J. P. GILL: Is the carbon WC or W_2C?

DR. S. L. HOYT: It is WC.

WRITTEN REPLY BY S. L. HOYT: Mr. McKenna has submitted a very interesting discussion on a pertinent point,—why is tungsten carbide so hard? Time has not permitted me to write an adequate reply to him, but it is my intention to discuss this and similar matters relating to this general field at a later date.

SOME PRACTICAL ASPECTS OF THE NITRIDING PROCESS

By H. W. McQuaid and W. J. Ketcham

Abstract

This paper discusses the nitriding process from a practical view point, and touches upon the usual method of nitriding, referring to the patents of Machlet and Fry covering the process and the steels suitable for nitriding. It touches upon the advantages and the disadvantages of the process and the Vickers method of indicating the hardness of the test pieces at different depths. Curves are given showing the effect of temperature, time, hydrogen concentration, cooling rate, and of reheating on the depth hardness curve.

A microscopical study is made showing the effect upon the structure of variations of these factors. Apparently raising the temperatures to about 1200 degrees Fahr. increases greatly the rate of penetration of the nitriding, but reduces the surface hardness. Reheating nitrided pieces to 1550 degrees Fahr. and quenching in water increases considerably the hardness of the nitrided case. According to the authors, the nitriding process requires no unusual care in operating and results are quite uniform. For general nitriding purposes, 1200 degrees Fahr. is recommended although it is found that at 950 degrees Fahr. a harder but much shallower case is obtained. Comment is made upon the commercial application of the process and some results in practice are described. Apparently the field for nitriding seems to lie in applications where low unit pressure prevails and where warpage and resistance to corrosion are important factors.

Results of Some Investigations Made to Determine the Best Commercially Satisfactory Nitriding Cycle

RECENTLY considerable publicity has been given to the surface hardening of steel by nitrogen, and many claims have been made and considerable effort exerted to commercialize this process.

Of the authors, H. W. McQuaid, member of the society, is metallurgist with the Timken-Detroit Axle Company and W. J. Ketcham is associated with him. Manuscript received August 21, 1928.

In March, 1908, Adolph W. Machlet, of Elizabeth, New Jersey, applied for a patent covering the treating of iron and steel articles as well as articles of some other compositions in a manner to produce upon the articles a skin, coat, or shell, by heating them in a retort heated from 900 to 1800 degrees Fahr., while a current of ammonia flows slowly through the retort. According to the patent granted on June 24, 1913, he describes a process in which iron and steel articles are treated at the above temperature in ammonia in a closed retort. The articles are held for a sufficient length of time to give the desired results, and cooled in the retort in an atmosphere of ammonia. According to his patent, the articles have the following characteristics, that is:

"The articles when examined after cooling, are found to be provided with an integral alloyed skin, casing, shell or coating, which when polished has a dull silvery color, and is very compact and close-grained and hard, and is capable of taking a very high polish closely resembling polished silver. It is so hard that it is difficult to polish, and difficult or impossible to cut with an ordinary machinist's file. This coating is extremely reluctant to tarnish, corrode, rust, or oxidize; and under ordinary conditions may be regarded as practically proof against oxidation or rust, as for instance in indoor use, or where it is not unduly exposed to the elements.

"Articles made according to this invention have been submitted to many tests at the same time with common steel untreated screws and other articles; and while the latter rusted in the expected manner, the former showed no signs of rust or even oxidation. The invention is therefore of value in treating parts of machines and instruments, to prevent their rusting, and give them an attractive finish, and avoid the necessity of nickeling, silvering or otherwise plating or finishing them; while the hardness of the shell renders it desirable for certain wearing parts, cutlery, and in numerous other arts. This silvery casing is much harder than either cast iron or low carbon steel. It is brittle, but owing to the presence of the softer metal beneath said shell, the brittleness is found unobjectionable in practice."

He also recommends the use of pure ammonia to which an excess of hydrogen has been added. He does not describe specifically any alloy steel or special steel but confines his claim to a general inclusive term "Iron and Steel". The first four claims of his process are as follows:

"1. The process of treating iron or steel, consisting in heating the metal in an atmosphere of ammonia.

"2. The process of treating iron or steel, consisting in heating the metal to at least 900 degrees Fahr. and below the melting point in an atmosphere of ammonia.

"3. The herein described process, consisting of exposing iron or steel articles when heated, to an atmosphere of ammonia.

"4. The process of treating steel of either low or high carbon, consisting in exposing the same when heated above redness, to an atmosphere of ammonia alone."

In 1921 Adolph Fry of Essen, Germany, applied for a patent on a method of hardening of alloy steels by nitrogenization. He describes the disadvantages of the nitriding process as usually carried out due to high temperature as giving marginal layers which are brittle and tend to peel off. His invention is based upon the claim that:

"The invention is based on the discovery that steel alloys which have absorbed nitrogen, undergo a peritectoidal transformation, which takes place at a temperature of about 1075 degrees Fahr. (580 degrees Cent. If the nitrogenization takes place below the peritectoidal transformation temperature, the concentration of the nitrogen remains below the limit at which the brittle layers are formed. In this case the steel receives the iron nitride in solid solution to a certain depth and not principally as nitride of iron only as in the known process. The marginal layer formed exhibits a texture which possesses the characteristic features of the hardening texture of the steel (of the martensite) and therefore acquires a high degree of hardness. The transition from the hard marginal layer to the core takes place quite gradually, and the marginal layer consequently has no tendency to peel off. The hardness diminishes slowly towards the core in proportion as the amount of nitrogen contained decreases."

To quote further:

"The above described process is only suitable for alloyed steels; ordinary carbon steels do not acquire any great degree of hardness when they are subjected to the action of substances which give off nitrogen such as ammonia for example. The process has been found to be particularly suitable for application to such ternary and quaternary steel alloys which contain aluminum, chromium, manganese, or silicon either separately or in any desired combination. A special increase in the hardness takes place already when one of the above elements is present to the extent of

only a few per cent. Thus, for example, the Brinell hardness of an improved steel containing 0.39 per cent carbon and 2.88 per cent chromium is increased by being heated in a current of ammonia at 932 degrees Fahr. (500 degrees Cent.), from 282 to 471. The hardness of an improved steel containing 0.44 per cent carbon, 1.07 per cent manganese and 1.93 per cent chromium was increased under the same treatment from 298 to 500."

The claims which were granted to Dr. Fry as set forth in his patent No. 1,487,554, granted March 18, 1924, are as follows:

"1. Process for hardening a steel alloy, consisting in subjecting the alloy to nitrogenization at a temperature below the temperature of peritectoidal transformation.

"2. Process for hardening a steel alloy containing aluminum, chromium, manganese or silicon in any desired combination, consisting in subjecting the alloy, at a temperature below the temperature of peritectoidal transformation, to the action of a substance which gives off nitrogen."

The development in recent years of interchangable parts which require grinding limits 0.001 of an inch or less, brought to the attention of the manufacturer of such parts the fact that warpage seemed to be an inherent disadvantage of case hardened parts, particularly those made from certain grades of steel and those made of nonuniform section. The cost of the scrap due to rejections from this cause has been very great and a process of heat treating which would eliminate losses caused by distortion in finished parts would be of great commercial advantage. For this reason the publicity given to the Fry claims immediately caused the metallurgical and manufacturing interests to sieze upon it as a long looked for method of hardening steel without distortion. Dr. Fry in an investigation had determined so-called peritectoidal points above which the nitriding case was unsuitable for commercial use, and below which it was very satisfactory. He also showed that certain elements formed stable nitrides which very much increased the hardness of the surface by nitriding, while with the plain carbon steels, a surface was obtained which would be file hard, but in which the increased hardness was only a few 10/1000 of an inch in depth and which would not resist commercial loads usually met with in operation. For this reason, the Fry discovery that the addition of aluminum, chromium, etc., to steel for nitriding, gave a commercially satisfactory case was of the utmost importance. Apparently metals such as aluminum, chromium,

molybdenum, etc., which form nitrides more easily than others are desirable additions to steel for this purpose. While Dr. Fry, in his original article, does not mention molybdenum, it developed later that molybdenum was of greater importance and perhaps essential to a commercially satisfactory nitriding steel. In this connection there are several other elements which have not been commercially developed, but which might in the future prove satisfactory for this purpose, such as boron, copper, etc.

Vanadium has been treated and found to be very satisfactory, replacing aluminum if necessary. Aluminum steels have in the past been looked upon as undesirable by the average metallurgist, and much publicity has been given to the undesirable properties of steel containing segregated alumina. For this reason, while practically every alloy heat of steel made is treated with aluminum to insure degasification, this fact has been kept very much in the background by the steel maker, although it has been felt to be a necessity.

A study of the physical properties of nitriding steels containing the high aluminum content indicate that these steels have properties which are in a sense very desirable, for instance, a steel made with the following analysis:

	Per Cent
Carbon	0.30–0.40
Manganese	0.40–0.60
Silicon	0.30 max.
Chromium	1.25–1.75
Molybdenum	0.15–0.25
Aluminum	1.00–1.25

When quenched from 1650 degrees Fahr. in oil and tempered at 1000 degrees Fahr., showed the following physical properties:

Yield Point Lbs. Per Sq. In.	Ultimate Strength Lbs. Per Sq. In.	Per Cent Elong. in 2"	Per Cent Reduction of Area	Charpy Ft. Lbs.	Brinell
158,500	182,500	15.0	50.0	22	363

indicating that the core of a nitrided article using this steel should have properties which are considerably better than those of any competing case hardening grade of steel. An electric furnace nitriding steel of the following analysis had the following physical properties when quenched at 1550 degrees Fahr. and tempered at 1000 degrees Fahr.

	Per Cent
Carbon	0.24
Manganese	0.87
Sulphur	0.018
Phosphorus	0.016
Silicon	0.47
Molybdenum	0.81
Aluminum	0.80

Yield Point Lbs. Per Sq. In.	Ultimate Strength Lbs. Per Sq. In.	Per Cent Elong. in 2"	Per Cent Reduction of Area	Charpy Ft. Lbs.	Brinell
137,300	160,900	18.0	59.8	29	340

In can be seen that nitriding steels of this special analysis do not lend themselves at the present time to cheap commercial production, but there is no reason why if the demand develops that such steels cannot compete with the more expensive special alloy steels used for case hardening purposes. At the present time the cost of nitriding steels is sufficient to limit greatly the use of this art. The actual nitriding operation due to the fact that it operates at a much lower temperature and requires less attention, can be done at less cost than the carburizing and hardening operations. In determining whether or not a part should be nitrided, the most important consideration, of course, is the final cost of the finished article. If the cost of rejections due to distortion, soft work, etc., is high, it may be found that for some parts the present price of the nitriding steel is not excessive. For this reason, many parts will be nitrided in spite of the handicap which the nitriding process has due to the high cost of these special steels. For applications where corrosion resistance properties are important, a nitrided piece offers considerable advantage over the case hardened piece. There has been, however, much variation in the results obtained by different users as far as the corrosion resisting properties are concerned, ranging from results equal to stainless iron in some cases to absolutely unsatisfactory results in others. Whether this has been due to some slip-up in the actual process or not, we have not been able to determine. It is, however, an established fact that most tests have shown the nitrided steel to be resistant to rusting in the atmosphere, and also quite resistant to the salt spray test. The advantages of the nitriding process lies in offering a relatively easily controlled method of obtaining surfaces which are extremely hard, which are uniform, and which are more resistant to corrosion than case hardened pieces. It is, however, subject to the dis-

advantages that the surface is accompanied by a certain brittleness, so that sharp edges become undesirable, and also that the extremely hard surface is of very shallow depth and decreases sharply to a relatively low Brinell hardness. It also does not seem to be well adapted to alternate stresses, such as would be met with in ball or roller bearing service, although very excellent reports have been obtained of satisfactory results with gear teeth in France and Germany which would indicate ability to stand up under such loads. The nitrided surface has the advantage that it retains the hardness at high temperatures as compared to the case hardened surface. For this reason, it might be advantageously used where high temperatures are met with in service.

In view of the apparent importance of the nitriding art, especially to the automotive industry, the following investigation was made to determine what the practical commercial limitations of the process were, and to obtain if possible the best commercially satisfactory nitriding cycle. In this investigation no effort was made to determine what anlysis of steel would be most suitable to nitriding, this being a problem which would require special investigation in itself. An effort was made to avoid spending much time upon the highly technical phases of the nitride constituents and the theoretical aspects of the nitriding process. Four different steels were experimented with of the following analyses:

	S.A.E. 1020	S.A.E. 4615	Chromium-Aluminum	Molybdenum-Aluminum
Carbon	0.17	0.14	0.45	0.33
Manganese	0.41	0.53	0.48	0.67
Phosphorus	0.020	0.024	0.028	0.022
Sulphur	0.034	0.025	0.021	0.020
Silicon	0.15	0.26	....	0.47
Chromium	....	0.27	1.68	....
Molybdenum	....	0.27	....	0.77
Nickel	....	1.64	....	....
Aluminum	....	....	1.59	0.87

These steels were machined after normalizing in the bar section into small test pieces $\frac{1}{4} \times \frac{7}{16} \times 1$ inch. These pieces were used throughout the investigation for microsections and hardness testing. It was believed that to the commercial user of the nitriding art it would be important to known the exact characteristic of the hardened case and the depth-hardness relation. For this reason, an effort was made to determine the hardness of the case

at various depths and after vainly trying all the means at hand, it was found that the Vickers diamond pyramid hardness tester offered a very satisfactory method for determining the hardness at any depth. G. M. Eaton of the Molybdenum Corporation of America developed an adjustable vise which permitted the making of Vickers indentation at fixed distances apart so that it was possible to obtain uniformally spaced and formed impressions from

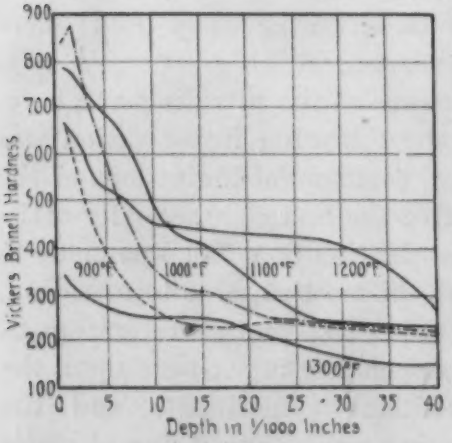


Fig. 1—Effect of Temperature on the Case of Molybdenum-Aluminum Steel 20 Hours in Anhydrous Ammonia.

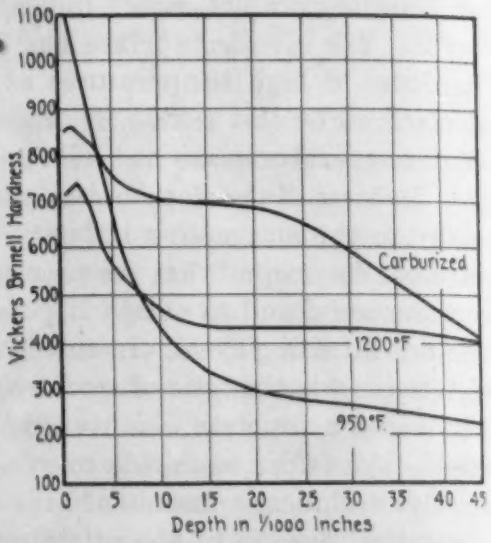


Fig. 2—Effect of Temperature on the Case of Molybdenum-Aluminum Steel 60 Hours in Anhydrous Ammonia. Also Molybdenum-Aluminum Steel Carburized 15 Hours, and Quenched in Water.

the surface to the core of the test piece. By grinding the face of the test piece at an angle of three degrees and spacing the impressions at intervals of 1/60 of an inch, it was possible to obtain the hardness in increments of 0.0008 inches in making a hardness test curve. This method was employed with very satisfactory results. The Vickers machine reads directly in Brinell hardness on a scale which gives increasingly divergent readings as the hardness increases as compared with the standard Brinell.[1]

This method used in connection with nitriding parts has been described by G. M. Eaton in his paper presented at the annual meeting of this society in Philadelphia October, 1928.

An effort was made in this investigation to determine whether or not the presence of braunite in the peritectoidal zone described

[1]See article describing the Vickers Diamond Pyramidal method of hardness testing by R. E. Smith and G. E. Sandland, Volume 1 of the 1925 *Journal*, Iron and Steel Institute.

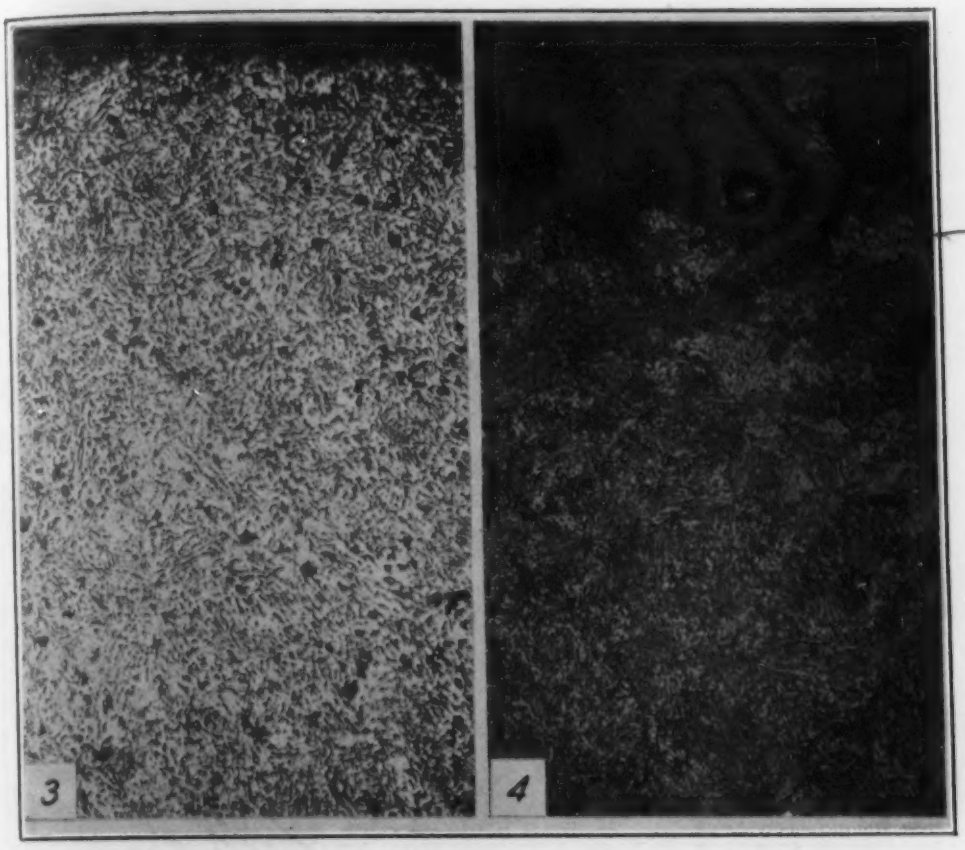


Fig. 3—Molybdenum-Aluminum Steel Nitrided 20 Hours in Ammonia at 900 Degrees Fahr. Etched 4 Per Cent Nitric Acid. × 100. Fig. 4—Molybdenum-Aluminum Steel Nitrided 20 Hours in Ammonia at 1000 Degrees Fahr. × 100.

by Dr. Fry, was of vital and commercial importance, but for some reason not known to the writers it was exceedingly difficult to develop any difference in structure in the steels used by different methods of nitriding.

Effect of Temperature Upon Nitrided Case

The first investigation was to determine the effect of the temperature upon the nitrided case. Fig. 1 shows the depth-hardness curves for test pieces nitrided for 20 hours at the temperatures shown. The maximum hardness is reached at 1000 degrees Fahr. and the maximum depth at 1200 degrees Fahr. It is evident from these curves that the nitrided case builds up faster on the surface as the temperature is increased to approximately 1000 degrees Fahr. Above this temperature, the diffusion of nitrogen becomes

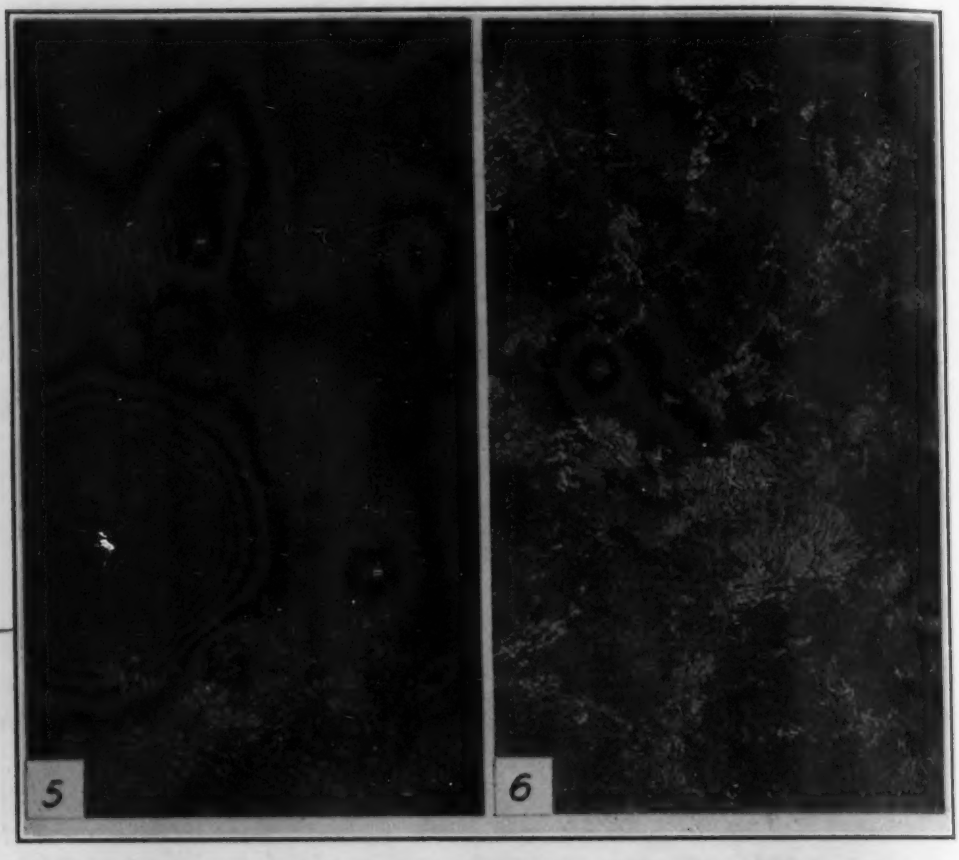


Fig. 5—Molybdenum-Aluminum Steel Nitrided 20 Hours at 1100 Degrees Fahr. in Ammonia. Fig. 6—Molybdenum-Aluminum Steel Nitrided 20 Hours at 1200 Degrees Fahr. in Ammonia.

more rapid and the case tends to get deeper but not so hard on the surface. At 1300 degrees Fahr. the nitriding effect decreases due probably to the more rapid diffusion of the nitrogen and the allotropic change in the ferrite. It may also be due to the change in the dissociation rate of the ammonia and the more rapid reaction of the hydrogen with the steel, or it may be a combination of all three. The case obtained at 900 degrees Fahr. is shallower and not so hard as at 1000 degrees Fahr. indicating that this is near the minimum nitriding temperature. Fig. 2 shows the case obtained at 950 and 1200 degrees Fahr. for 60 hours. Here an extremely hard case is obtained at 950 degrees Fahr. which is, however, very shallow, falling off from 1050 to 425 Brinell in 0.010 inch. At 1200 degrees Fahr. the case is not so hard, but very deep, being above 400 Brinell for 0.050 inch. An interesting

point is shown by plotting a depth hardness curve of the same material carburized for 15 hours, cooled in the pot and then reheated to 1500 degrees Fahr. and quenched in water. This case is not only harder, but much deeper than the 1200 degrees Fahr. nitrided case, indicating that the advantage of the nitriding may be due more to its lack of distortion than to superior hardness. It is evident, however, than when nitriding below 1000 degrees Fahr., a long period of time is necessary.

The microsections, Figs. 3, 4, 5 and 6, show the character of the case at 100 diameters. These sections were etched with 4 per cent

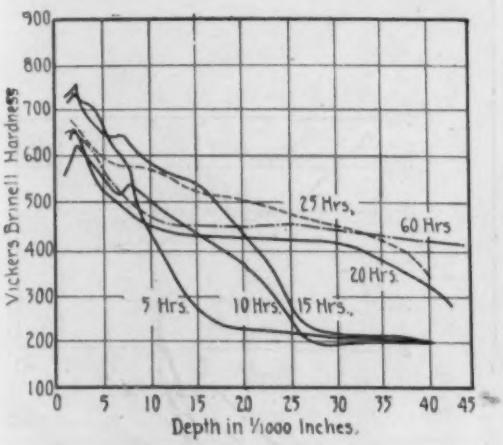


Fig. 7—Effect of Time on Case of Molybdenum-Aluminum Steel—Anhydrous Ammonia at 1200 Degrees Fahr.

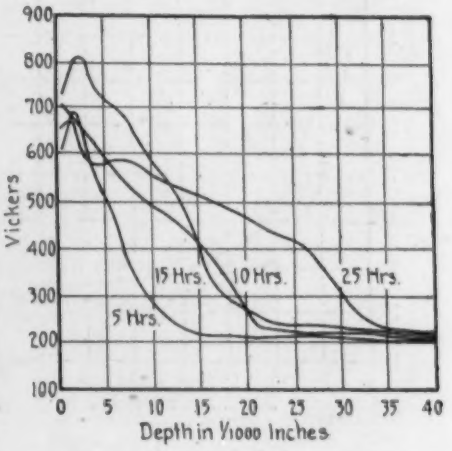


Fig. 8—Effect of Time on Case of Chromium-Aluminum Steel — Anhydrous Ammonia at 1200 Degrees Fahr.

nitric acid in alcohol. If picric acid is used, the change in structure shown is very much less than with nitric acid, and since the nitric acid etch reveals the disturbed area corresponding to the depth hardness curve, it was decided that this etch would be more illustrative.

Fig. 3 shows practically no effect of nitriding except at the extreme edge. Fig. 4 shows approximately ¼ of the depth as affected by the nitriding. Fig. 5 shows approximately ¾ of the depth of the microsection affected by the nitriding. Fig. 6 shows practically the whole photograph depth affected by the nitriding. In none of these sections is there any evidence of the so-called "braunite" and the Vickers tests revealed no brittle edge. Even at magnifications of 500 diameters very little real difference could be found between the 1200-degrees Fahr. nitriding and the 900-degree Fahr. nitriding. There was no evidence of nitride needles

in steels high in aluminum, and it is our opinion based on the many pieces examined, which were nitrided at various temperatures, that braunite and the brittle surface shown by Dr. Fry is characteristic of the plain carbon steels, but is apparently not very marked in steels containing aluminum. The Vickers tests indicate by cracking of the impression that steels containing high chromium and aluminum, but no molybdenum, are quite brittle in their out-

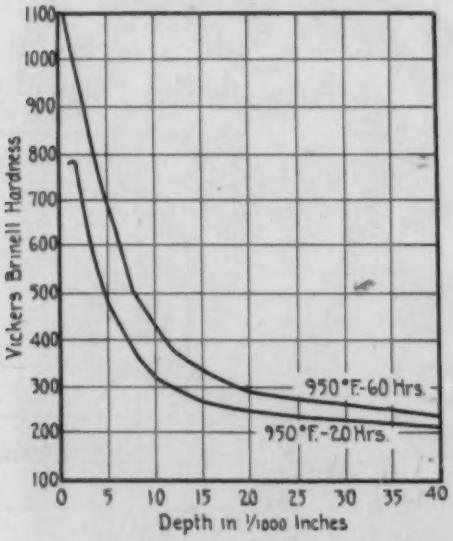


Fig. 9—Effect of Time on Depth-Hardness Curve of Molybdenum-Aluminum Steel Treated at 950 Degrees Fahr. in Anhydrous Ammonia.

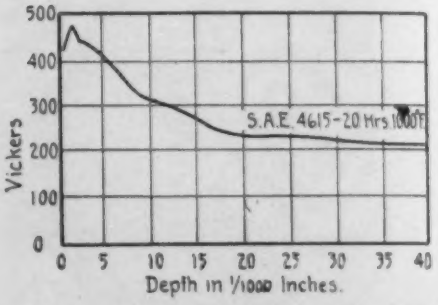


Fig. 10—Depth-Hardness Curve—Nickel-Molybdenum, S.A.E. 4615 Steel 20 Hours at 1000 Degrees Fahr. Note that the Surface is File-Hard but Too Thin to Affect Hardness Test.

side layers. The coarse grain observed in Fig. 6 seems to be traceable to the hydrogen effect, as the same coarsening is obtained by treating the sample in hydrogen without ammonia.

The Effect of Time on the Case

Fig. 7 shows a depth-hardness curve obtained by nitriding at 1200 degrees Fahr. for various lengths of time. These curves show that the surface hardness falls off as the time is increased, and that the maximum hardness at this temperature is apparently obtained in 15 hours. There is little to choose in depth between 10 and 15 hours and the effect at 5 hours nitriding is not apparently of commercial importance. The 20 and 25-hour cases are considerably deeper than the 10 and 15-hour cases, indicating that the diffusion of the nitride is apparently dependent upon some struc-

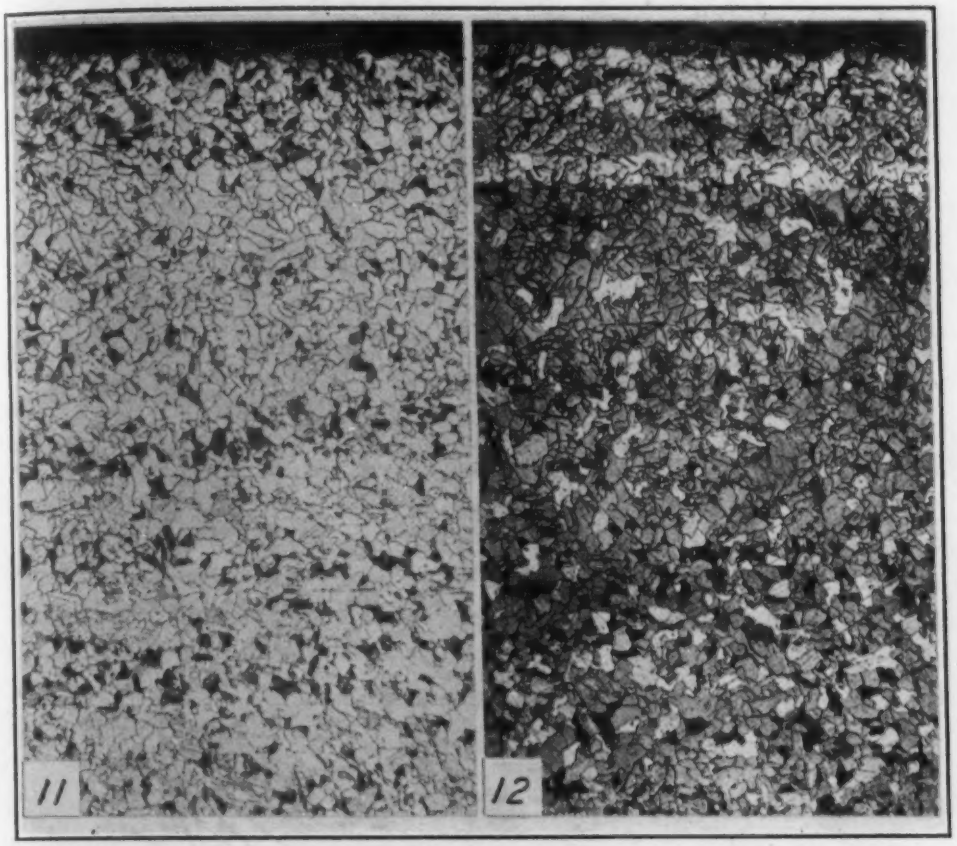


Fig. 11—Core of S.A.E. 4615 Nickel-Molybdenum Steel Held at 1200 Degrees Fahr. for 20 Hours in Anhydrous Ammonia. Fig. 12—Case of S.A.E. 4615 Nickel-Molybdenum Steel Held at 1200 Degrees Fahr. for 20 Hours in Anhydrous Ammonia. Note Needles—Maximum Brinell 300.

tural change which requires at least 15 hours for completion.

Fig. 8 shows the results obtained with similar variations in time, but with a chromium-aluminum steel without any molybdenum. These cases were also obtained at a temperature of 1200 degrees Fahr.

Fig. 9 shows the difference between 20-hour and 60-hour runs at 950 and 1200 degrees Fahr. Here it will be seen that the 60-hour run is very similar to the 20-hour run at 1200 degrees Fahr. with the exception that the longer time has resulted in considerable increase in depth. At 950 degrees Fahr. the increase in time has not resulted in a very great increase in depth, but has resulted in a considerably harder surface, indicating that at this temperature there is not much to gain by prolonging the time over 20 to 30 hours. On a larger scale in an electrically heated furnace using a

retort with a capacity of approximately 5 cubic feet, it was found that after 24 hours there was not much gain in depth, and that under commercial conditions this time would produce cases which were remarkably uniform in depth and in characteristics.

The Effect of Ammonia Hydrogen Relation

At the time this investigation was started, it was the opinion of most of the experimenters that nitriding required some care in the selection and operating conditions of the process. It was commonly reported that the ammonia-hydrogen relation was of considerable importance, and that the presence of oil, vapor, oxides, etc., had a very adverse effect upon the results. Tests were made in which nitriding runs were made with ammonia and also with ammonia plus varying amounts of hydrogen. Fig. 13 shows the curve obtained by nitriding for 15 hours at 1225 degrees Fahr., using in one case anhydrous ammonia and in the second case anhydrous ammonia plus an equal amount (approximately) of hydrogen. These volumes were checked by approximating the number of bubbles discharged per second under equal pressures of water. This method, while crude, was sufficiently accurate to prove whether the excess hydrogen had an adverse effect upon the nitriding operation.

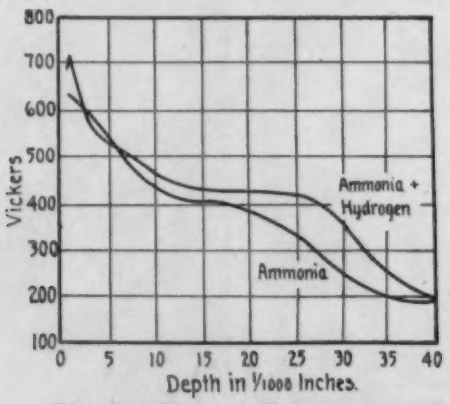


Fig. 13—Effect of Hydrogen-Ammonia Relation on Molybdenum-Aluminum Steel —15 Hours at 1225 Degrees Fahr.

Fig. 13 indicates that a more satisfactory case was obtained with the hydrogen excess than with the pure anhydrous ammonia. This is characteristic of results obtained at other temperatures with the exception that the hydrogen effect decreases very rapidly

Table I
Effect of Nitriding Operation on Drillings—20 Hours at Temperature Shown

	Molybdenum-Aluminum Carbon Content Per Cent	S.A.E. 4615 Carbon Content Per Cent
Original Carbon	0.33	0.14
900 degrees Fahr., Ammonia	0.27	0.14
900 degrees Fahr., Hydrogen	0.26	0.14
950 degrees Fahr., Ammonia	0.14	0.08
950 degrees Fahr., Hydrogen	0.14	0.07
1100 degrees Fahr., Ammonia	0.02	0.00
1100 degrees Fahr., Hydrogen	0.00	0.00

as the temperature is reduced. According to H. A. De Fries[2] "it was found that a high degree of free hydrogen will produce a decarburization of the upper case with attending swelling and sponginess. For this reason, the dissociation of the ammonia was decreased from 30 per cent to 10 to 15 per cent maximum. The latter ratio will only produce sponginess in the very uppermost film, but will not affect the case proper."

We have also found that nitriding is accompanied by decarburization, but we do not find that this decarburization is primarily a factor in the sponginess or brittleness of the case or that increasing hydrogen will cause any increase in brittleness. It is a fact, however, that the disassociated hydrogen may have a somewhat different effect upon the material being nitrided than hydrogen, as such. However, it is a well known fact that the disassociation decreases with the temperature, reaching a maximum at approximately 1200 degrees Fahr., but we have found no indication that sponginess and swelling are necessarily a result of the higher temperature.

A series of tests were run in which chips from test pieces were held in an atmosphere of hydrogen at various temperatures for 20 hours. Table I shows the analyses of the drillings before and after the hydrogen treatment. At the same time similar drillings were treated by nitriding at the temperatures given and analyses were made as shown in Table I. It is evident from the above that nitriding is accompanied by a decarburization due to the hydrogen reaction, and that this decarburization increases as the temperature

[2] TRANSACTIONS, American Society for Steel Treating, December, 1927, page 946.

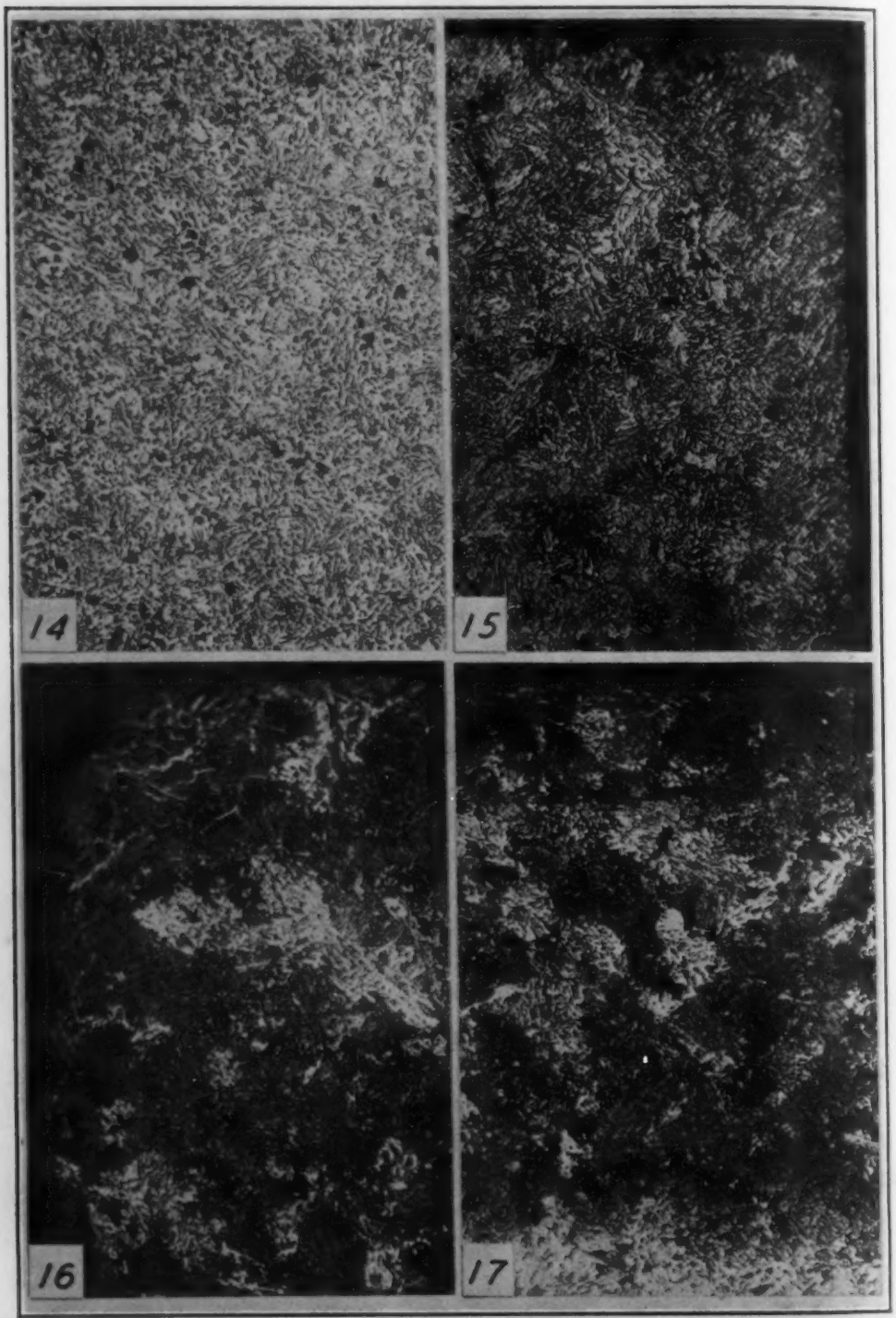


Fig. 14—Core of Molybdenum-Aluminum Steel Nitrided 20 Hours in Anhydrous Ammonia at 1100 Degrees Fahr. Fig. 15—Corner of Molybdenum-Aluminum Steel Heated 20 Hours in Hydrogen at 1100 Degrees Fahr. Fig. 16—Corner of Molybdenum-Aluminum Steel Nitrided 20 Hours—Anhydrous Ammonia at 1100 Degrees Fahr. Fig. 17—Edge of Molybdenum-Aluminum Steel Nitrided 20 Hours—Equal Parts Ammonia and Hydrogen at 1100 Degrees Fahr.

of nitriding increases. It is difficult to determine the extent of decarburized surface, but since the nitriding process is accompanied by an increase in weight, it is probable that the removal of the carbon is accompanied by the substitution of nitrogen. The measurement of the decarburization by analyzing the chips does not permit an absolutely accurate comparative determination of the loss at different temperatures, due to the difficulty in obtaining chips of uniform thickness.

Fig. 14 shows the core structure of a molybdenum-aluminum nitriding steel after 20 hours at 1100 degrees Fahr. Fig. 15 shows the corner of a test piece from the same bar after 20 hours at 1100 degrees Fahr. in hydrogen. The coarsening of the structure as compared to Fig. 14 is quite evident. Fig. 16 shows the corner of a similar test piece after 20 hours at 1100 degrees Fahr. in anhydrous ammonia and cooled at 50 degrees Fahr. per hour to 800 degrees Fahr. Fig. 17 shows the case of a test piece nitrided for 20 hours in an atmosphere of equal parts of anhydrous ammonia and hydrogen. The nitride network shown at the corner of Fig. 16 is characteristic of this steel nitrided at 1100 degrees Fahr., whether the excess of hydrogen is present or not. It is possible that the decarburizing action of the hydrogen at the higher temperatures is responsible for the decreased hardness obtained at these temperatures and that the process described by Adolph W. Machlet in his patent No. 1,092,825 granted April 14, 1914, might be advantageously used to obtain increased surface hardness. In this patent he describes the bubbling of the ammonia through naphtha, so that the hydrocarbon gases will be mixed in the retort with the disassociated ammonia. This might effectively decrease the decarburizing of the work being nitrided. This does not seem probable in view of the fact that excess hydrogen seems to increase the hardness if anything of the nitrided samples.

Effect of Cooling Rate

Figs. 18, 19, and 20 show the corners of test pieces nitrided at 1100 degrees Fahr. for 20 hours in anhydrous ammonia. In Fig. 18 the test piece has been quenched directly from the nitriding temperature into water. Fig. 19 the test piece has been allowed to cool from the nitriding temperature in air. Fig. 20 the test piece has been cooled at the rate of 50 degrees Fahr per hour in a closed retort containing atmospheric air. In Fig. 18 the structure is some-

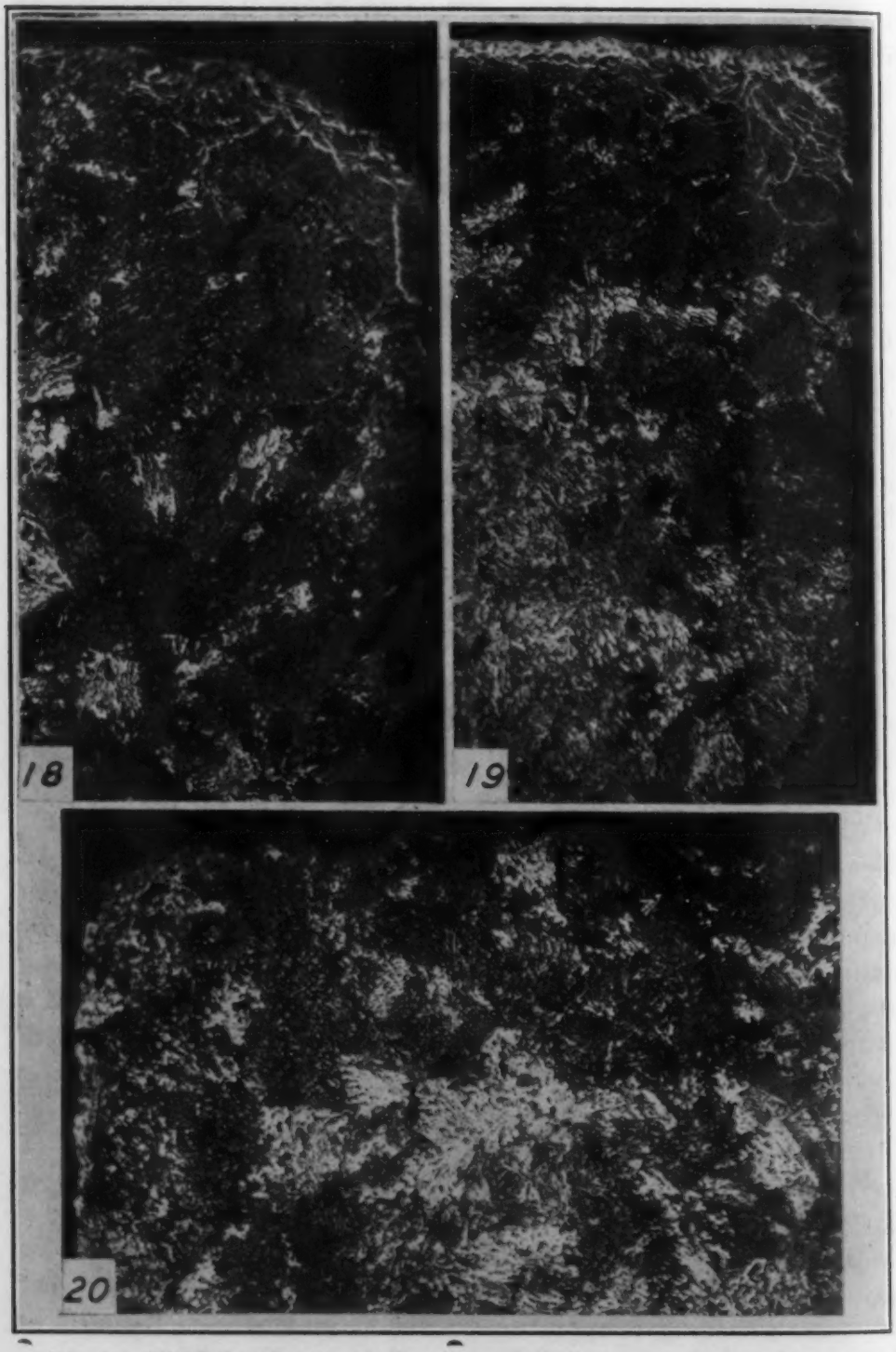


Fig. 18—Molybdenum-Aluminum Steel—20 Hours in Anhydrous Ammonia at 1100 Degrees Fahr. Quenched in Water from 1100 Degrees Fahr. Fig. 19—Molybdenum-Aluminum Steel 20 Hours in Anhydrous Ammonia at 1100 Degrees Fahr. Cooled in Air from 1100 Degrees Fahr. Fig. 20—Molybdenum-Aluminum Steel—20 Hours in Anhydrous Ammonia at 1100 Degrees Fahr. Cooled 50 Degrees Fahr. per Hour in Air to Room Temperature.

what darker than shown in Fig. 19 in which, however, the nitride network is much more evident. Fig. 20 shows that under these conditions of cooling, the nitride network has been suppressed. It is believed that this is perhaps due to the oxidation effect obtained by the relatively longer time in contact with oxygen at elevated temperature. It has been found that certain rates of cooling have considerable effect upon the character of the nitrided case; that produced by slow air being often quite brittle and in one or two instances powdery and soft. It is believed that there is a critical rate of cooling, at which unsatisfactory case conditions are obtained, particularly with plain carbon and other steels containing low nitride concentration. Cooling to 800 degrees Fahr at 50 degrees Fahr. per hour has been found to produce very uniform results. Figs. 21 and 22 show the peculiar effect observed in one case where two pieces which were being nitrided together were cooled at different rates. These pieces were in actual contact in a retort held at 1150 degrees Fahr. for 24 hours. The test piece in Fig. 21 was withdrawn and allowed to cool in air at 950 degrees Fahr. The test piece in Fig. 22 was allowed to cool in the retort at 50 degrees Fahr. per hour to 800 degrees Fahr. Both pieces were from the same bar of molybdenum-aluminum nitriding steel and it is difficult to account for the difference in depth in each case. It is customary to find after cooling at this rate that the corners of the test pieces show a network of the white nitrides. This network seems to be more pronounced with a nitriding cycle of 1100 degrees Fahr than at temperatures either above or below. Fig. 23 shows the effect on the depth-hardness curve of different cooling rates. It will be noticed that there is little to choose between these curves but that the test piece which cooled slowly (50 degrees Fahr. per hour) to 800 degrees Fahr. shows the greatest depth and maximum hardness excepting at the surface, where the test piece cooled at 50 degrees Fahr. an hour to 1100 degrees Fahr. from 1200 degrees Fahr. shows the greatest hardness. This surface hardness corresponds to the results obtained by nitriding at this temperature where we find that nitriding at 950 to 1100 degrees Fahr. with this steel seems to give the highest surface hardness.

Stability of the Case

The test pieces after nitriding were reheated at different temperatures varying from 1200 to 1700 degrees Fahr. and held for

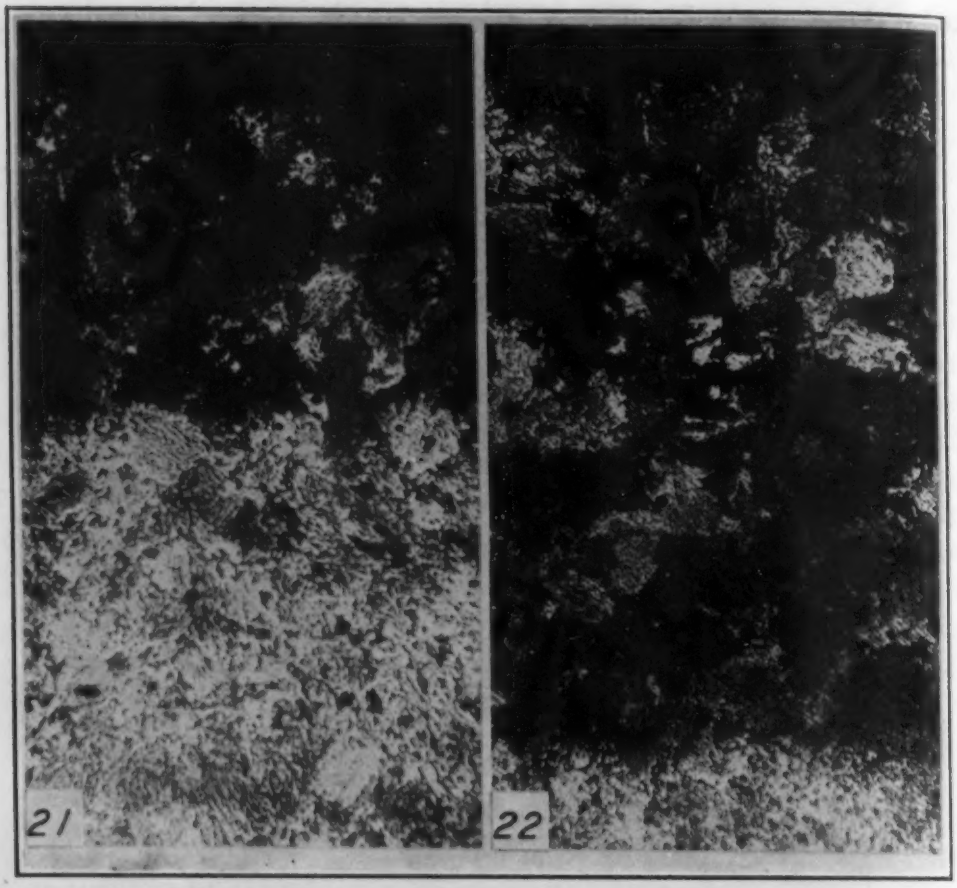


Fig. 21—Molybdenum-Aluminum Steel 24 Hours at 1150 Degrees Fahr. in Anhydrous Ammonia—Cooled 50 Degrees Fahr. per Hour to 950 Degrees Fahr. in Retort, and cooled Rapidly to Room Temperature in Air. Fig. 22—Molybdenum-Aluminum Steel 24 Hours at 1150 Degrees Fahr. in Anhydrous Ammonia (in Contact with Test Piece of Fig. 21). Cooled 50 Degrees Fahr. per Hour to 800 Degrees Fahr. and Cooled Rapidly to Room Temperature in Air.

1 hour at temperature and cooled in air. The hardness as indicated by the file is not affected by the treatment and no apparent effect on the nitride case was observed under the microscope indicating that the nitrides upon which the hardness of the surface depends are stable at these temperatures. This checks the results given by Dr. Fry in which he shows that the aluminum nitrides are stable up to 1800 degrees Fahr. and indicates that the hardness of the nitrided case is primarily dependent upon the aluminum nitride.

Nitrided test pieces were reheated to 1550 degrees Fahr. and quenched in water. Fig. 24 shows a comparison between samples after quenching and the original case. It will be noticed that there is considerable increase in hardness both in the core and the

case of the test pieces checked. In the case of the sample which has been nitrided at 1200 degrees Fahr. the effect is peculiar in that there is a drop in the curve at a depth of from 15 to 30 thousandths which is difficult to explain. It is possible that this drop in the hardness curve in the nitrided test specimen may be due to the decarburizing action of the hydrogen which is quite

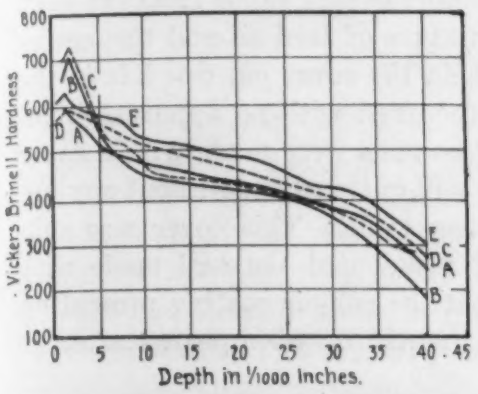


Fig. 23—Effect of Cooling Rate—Molybdenum-Aluminum Steel—1200 Degrees Fahr. for 20 Hours in Anhydrous Ammonia.
A—Cooled from 1200 Degrees Fahr. in Air.
B—Cooled 50 Degrees per Hour in Ammonia to 1100 Degrees Fahr. and Cooled in Air.
C—Cooled 50 Degrees per Hour in Ammonia to 1000 Degrees Fahr. and Cooled in Air.
D—Cooled 50 Degrees per Hour in Ammonia to 900 Degrees Fahr. and Cooled in Air.
E—Cooled 50 Degrees per Hour in Ammonia to 800 Degrees Fahr. and Cooled in Air.

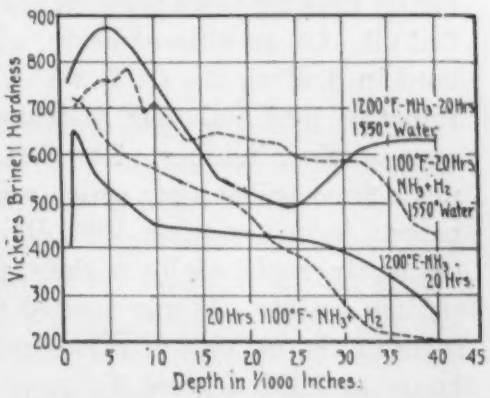


Fig. 24—Effect of Reheating and Quenching on Depth-Hardness Curves. Molybdenum-Aluminum Steel as Shown—Quenched 1550 Degrees Fahr. in Water.

marked at this temperature although it is doubtful that this effect would be felt at the depth shown. It is evident from these curves that heat treatment after nitriding is quite beneficial and it is expected that further investigation will be made in this direction.

General Observations

The nitriding process as we see it, offers a method of obtaining very high surface hardness with a minimum of distortion and can be done at temperatures which permit complete finishing of the object to be nitrided before this operation. This is a great advantage over the cyanide process or the case hardening process. It was first believed that the nitriding process was a very delicate process and required extreme care in all its phases. While this is true when nitriding at low temperatures, i.e., 950 degrees Fahr., at higher temperatures, around 1200 degrees Fahr. very little special

care need be given to the handling of the material or to the removal of oxide or other nonmetallic matter.

In a relatively large retort, very uniform results were obtained under quite adverse conditions. By accident a considerable amount of oil was left in the retort which volatilized and interfered with the ammonia circulation so that for the first hour at heat, practically nothing came through the retort except vapor from the gasified oil. On another occasion, a mixture of lard oil and turpentine used in drilling the studs which held the cover on, was left in the retort so that a similar reaction occurred with no apparent influence on the nitriding. The first two runs were made with a cover made from boiler plate which was still quite rusty, without any apparent influence upon the nitriding cycle. This cover was subsequently replaced by a sheet of nickel and the seal made with sodium silicate. It was noticed that the copper coating present on some of the articles nitrided had practically disappeared after 20 hours at 1200 degrees Fahr.

Nitrided work normally, is found, upon opening the retort, to have a slight discoloration but apparently unaffected surface. In the run in which the oil was present, in the retort, the work was found to be covered with a very sooty carbon deposit, which, however, did not seem to affect the nitrided case underneath. This experience is quite the opposite from what we had been led to expect, since we had been warned that special precautions were necessary to avoid the presence of oil vapor in the ammonia. The nitriding operation is considerably easier to control than the carburizing operation as the temperature variation is apparently less important and the penetration more uniform throughout the retort. The amount of ammonia seems also to be of minor importance provided one or two bubbles per second were passed. It was observed in handling chips after nitriding that they were quite nonmagnetic as compared with the chips before nitriding or from the hydrogen retort. This would indicate that there had been some allotropic change in the ferrite. This can probably be explained by the fact that nitrides are supposed to depress the critical range very greatly. One of the difficulties of the nitriding process is to obtain a gastight seal on the retort in which the nitriding is done. Inasmuch as the pressures are very low, seldom being more than one inch of water, it is not necessary to maintain an exceptionally strong seal, but it is necessary that the seal be as nearly as possible 100

per cent complete, since the escaping ammonia fumes are very objectionable and interfere with the proper control of the process. In our experiments, a nickel-chromium retort was used on which a sheet nickel cover was bolted with sodium silicate used as a seal. It is a practice in some plants to use a nickel wire between the cover and the retort and in others a special asbestos gasket.

Results in Practice

Tests have been made on nitrided worms furnished by different companies as well as by ourselves from chromium-aluminum steel and molybdenum-aluminum steels. Results indicate that the chromium-aluminum steel gives higher hardness. It showed a scleroscope hardness of 110, but was too brittle for even this application where the shock load is practically absent and the most important essential is the ability to withstand sliding friction. In this application the chromium-aluminum steel contact surface with the bronze worm wheels failed by checking after the second trial. It demonstrated, however, that the bearing characteristics were very satisfactory. The molybdenum-aluminum steel which showed a scleroscope hardness of only 70 gave a much more satisfactory surface and indicated that this material would be, if commercial, excellent for this application. Some trouble developed, however, where the rolls from an Hyatt roller bearing ran directly upon the nitrided surface. Here the surface failed by fatigue after several hours of very successful operation at high loads. Worms from the molybdenum-aluminum steel nitrided at 1200 degrees Fahr. by ourselves, in experimental service seemed to stand up very well. Several other applications of the nitriding process such as valve tappets have not given as good results as those case hardened or of special white cast iron generally used.

The writers have discussed nitriding results with several investigators who do not seem to have had uniformally successful results and who are not, therefore, quite as enthusiastic as they expected when entering into the nitriding field. Reports from abroad indicate, however, that they have been much more successful than we have and while we have been unable to accurately check the quality of the nitrided parts used in Europe, comparative results with present American practice would be very instructive. We have reports from a European manufacturer of worm gearing,

in which they report that they have had several sets of experimental nitrided worms in service in different parts of England and that these worms are doing very well and showing no signs of wear. They state further that:

"The process seems to have given the best results in cases where the ordinary methods of case hardening are entirely unsuitable owing to warpage or insufficient hardness of the case. The process seems to have met with a good deal of success in France for spiral timing gears where noise and wear with case hardened gears is, of course, always very serious. We have made some spiral timing gears ourselves by this process with excellent results."

They also report:

"A disadvantage of the process is the cost of the steel, which is at the present time approximately three times that of our standard nickel case hardening steel, and while the actual costs of hardening by nitrogen are slightly less than those obtaining with the ordinary methods the total increase in cost due to this method is an appreciable item."

Summary

The results obtained from the work which the writers have done as covered in this paper, indicate that for the hardest possible case the nitriding should be carried out at a temperature of approximately 950 to 1050 degrees Fahr. but at this temperature the hard case decreases very sharply to the softer core and the commercial hardening effect is apparently hardly more than 0.010 of an inch in depth. At higher temperatures a much greater depth is obtained but with sacrifice of surface hardness. Carburizing and quenching the same steel gives a case which is as hard as the higher temperature (1200 degrees Fahr.) nitrided work, but not as hard as the low temperature (950 degrees Fahr.) nitrided work. In case hardened material the case is apparently much superior to the nitrided piece insofar as the depth hardness curve indicates, being as hard 0.030 of an inch below the surface as the nitrided piece is 0.007 inch below the surface.

Practically any steel can be nitrided so that a very hard superficial surface can be obtained but this surface is less than 0.001 of an inch in thickness on plain carbon steels and the addition of aluminum or vanadium in combination with chromium or molybdenum is necessary to obtain a commercially satisfactory nitrided case for ordinary purposes. Distortion checking indicates that if a

nitrided piece is properly heat treated before machining that the distortion after nitriding will be practically negligible. Nitriding is accompanied by a growth which seems to be quite uniform and which amounts to approximately 0.001-inch per inch in diameter.

The process is apparently easily controlled and offers no operating difficulties as compared with the case hardening process.

The field for nitriding seems to lie in applications where low unit pressure prevails, as its brittleness makes it unsuitable for high alternating stresses, although some success has been reported in applications of this nature. Its corrosion resisting properties have been reported as being exceptionally good in some cases and not very good in others under the salt spray test. In ordinary atmosphere it is apparently very resistant to atmospheric attack.

In conclusion the writers wish to acknowledge their indebtedness to O. W. McMullan of the Timken-Detroit Axle Company for his painstaking work in preparing the microsections and making the Vickers hardness readings, and also the Molybdenum Coporation of America for their kindness in furnishing the special test specimen holder for the Vickers hardness tester.

PRINCIPLES OF THE HEAT TREATMENT OF STEEL
Part II

An Outline Prepared by the Metallurgical Staff of the Bureau of Standards[1]

(Continued from October issue of TRANSACTIONS*)*

SYNOPSIS OF PRECEDING CHAPTERS

Factors to be considered in heat treatment, including the effect of heat on high-carbon, low and medium-carbon steels and on iron and the effect of composition, are discussed in part one of this article. The names and structures of the constituents of steel and the iron-carbon diagram are explained. Effect and purpose of heating under which, the formation of austenite, heating of steel, homogeneity and grain size, good heat treatment a precision operation, rate of heating and furnace atmosphere are all covered in some detail. The general subject of annealing and normalizing under which stress release in and recrystallization of cold-worked steel, cooling from annealing temperatures, critical points and their relation to annealing temperatures and cooling rates are all quite fully explained, as well as the general subjects of normalizing for grain refinement, true annealing and spheroidizing.

CHAPTER IV

QUENCHING

Rate of Cooling for Hardening

THE fact that the temperature of formation of pearlite is lower on cooling than that of its disappearance on heating (Fig. 6), and that we may lower its formation temperature by increasing the cooling rate somewhat, indicates that it might be possible to get still different results by still more rapid cooling. We can, in fact, cool so rapidly that we form no pearlite at all, and it is due to this that we can harden steel so greatly by quenching.

The equilibrium diagram, Fig. 3, is a satisfactory guide for the study of the principles of annealing and normalizing, operations that involve such slow cooling rates that equilibrium is not greatly

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get the kind of hardness found in quenched steel, we are no longer dealing with equilibrium conditions and the equilibrium diagram does not apply in so far as carbon, iron carbide, cementite, and pearlite are concerned. The formation of cementite at Ar_1 and Ar_{cm} can be avoided by sufficiently rapid cooling.

At this point we must remember that there are two simultaneous actions at Ar_1. Cementite is precipitated from the austenite and at the same time the gamma iron in the austenite changes over the alpha iron or ferrite. We can slow down or entirely avoid the carbon change much more readily than we can the gamma to alpha change. It has sufficed to consider these two changes at Ar_1 together in the previous discussion, but in the balance of the discussion the mechanism of quenching and tempering will be made clearer by recalling that the two separate changes take place.

The "Split Transformation"; Martensite and Troostite

If we use an extraordinarily sensitive pyrometric outfit that will show the "halts" in the cooling curves during the few seconds elapsing in the quenching operation, Fig. 12, we find that as we progressively increase the speed of cooling we first drop the temperature of formation of pearlite, Ar_1; then we no longer get Ar_1 but a weaker critical point (denoted as Ar′) at a somewhat lower temperature and a very tiny second critical point (denoted as Ar″) at a *very* much lower temperature. The occurrence of the two transformation points, Ar′ and Ar″, instead of the one, Ar_1, is called the "split transformation." Microscopic examination of steel cooled in this manner shows that we have not formed pearlite at all, but have an entirely new and different product containing two new microconstituents; one, after suitable etching, shows up dark under the microscope, the other light and with a needle-like structure. At the same time the steel is much harder than a pearlitic steel. The two new microstructures, (as was the case with the austenite studied previously), are named for early metallographers, Troost and Martens. The dark structure is called *troostite*; the light, needle-like (acicular), very hard structure, is called *martensite*. We shall later meet a second sort of troostite; that which we have here is *primary troostite*.

As we still further increase the cooling rate we find, from our sensitive pyrometer, that Ar′ (the troostite point) is dropping in disturbed. On the other hand, when we cool at such a rate that we

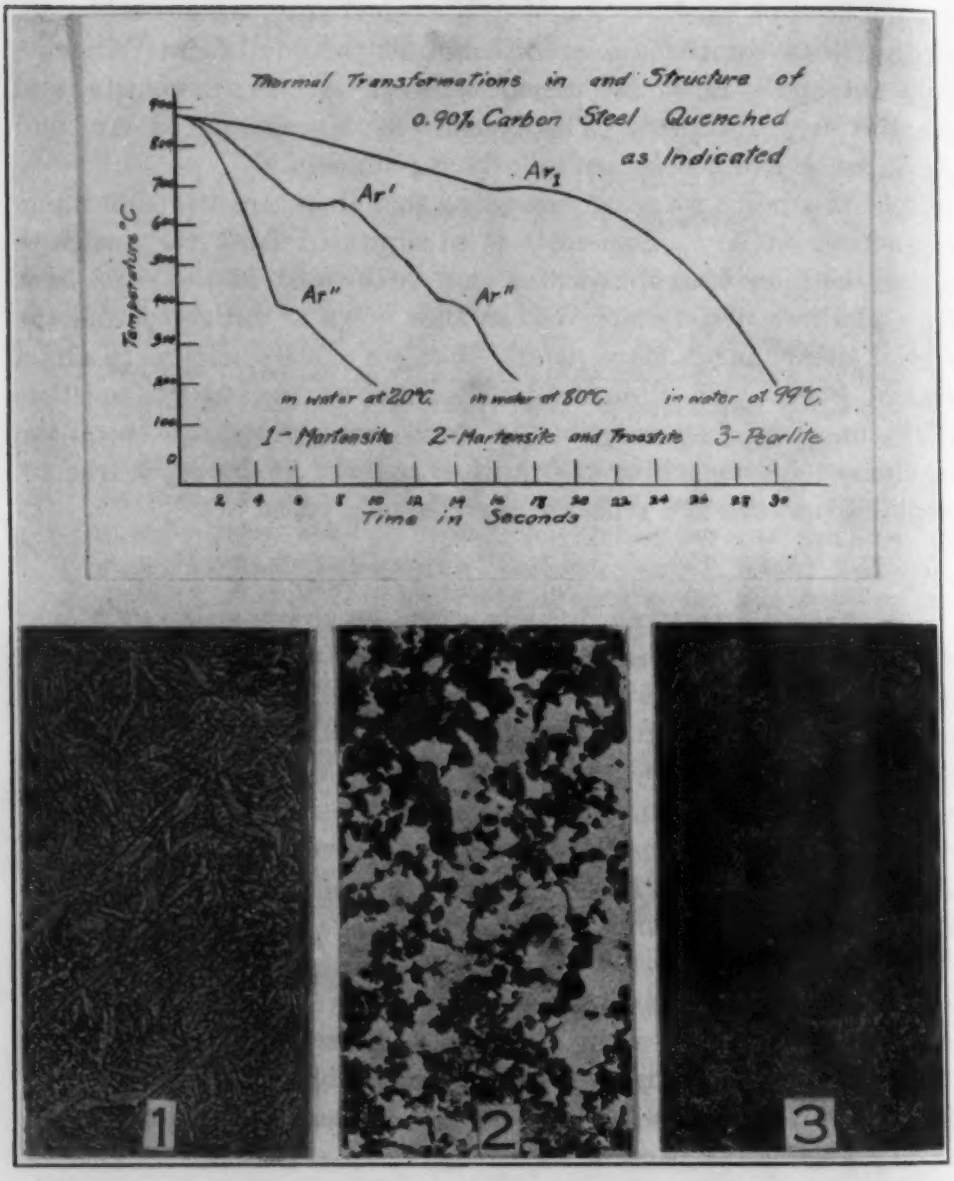

Fig. 12—Chart Showing Arrest Points in the Cooling Curves of a Carbon Tool Steel Quenched from Above the Critical Range at Different Speeds, and the Resulting Structures. On Fast Cooling in Cold Water the Ar_1 Point is Suppressed, but a Point Called Ar" Appears at a Lower Temperature, About 400 Degrees Cent. The Structure Obtained is Martensite (Micrograph 1). On Slower Cooling in Hot Water the Ar_1 Point is Still Suppressed; in This Case Two Points Appear at Lower Temperatures, Ar' at About 650 Degrees Cent. and Ar", as Before, at About 400 Degrees Cent. The Structure is a Mixture of Primary Troostite and Martensite (Micrograph 2. The Dark Patches are Troostite). On Still Slower Cooling in Boiling Water, the Ar_1 Point is not Suppressed. The Structure is Pearlitic (Micrograph 3). Etchant 5 Per Cent Picric Acid in Alcohol. 1 × 500 — 2 and 3 × 100.

temperature and getting weaker, Ar" (the martensite point) staying at about the same temperature and getting stronger; the hard-

ness of the quenched steel is rapidly increasing, and, in the microscopic structure, the amount of troostite decreases and that of martensite increases. Finally, at a sufficiently rapid rate, we have no more Ar′, only Ar″, no troostite, only martensite, (often with some retained austenite) and the steel is the hardest we can get by quenching.

Since martensite is born from austenite, and to get a steel containing a maximum amount of martensite we must pass through the temperature range at which $Ar_{3\text{-}2\text{-}1}$ would occur on slow cooling and Ar′ fast enough to hold back the changes there and thus reach the temperature of Ar″ with all the austenite unchanged, it is important that the austenite be brought into such a condition that it will easily cool down to Ar″ without any previous changes.

It is in that condition when the carbon is diffused uniformly. If we should quench from above Ac_1 but below Ac_3 where we start with both austenite and ferrite, the ferrite would act like a trigger to set off the reaction at Ar_1 and we would not get satisfactory hardening, even of the austenite present. If the steel is heated just above Ac_3, but not held there for any length of time, the last ferrite that has changed to austenite has not had time to soak up carbon from the previously formed austenite that is higher in carbon. The more carbon there is in austenite, up to the eutectoid composition, the more sluggish the steel is to transformation and the easier to harden; the less carbon there is, the more active it is and the harder to harden. So, with non-uniform austenite, the outer, lower carbon borders of each grain will readily change on passing Ar_1 and act as triggers to set off the change in the interior of the grain.

On the other hand, if time is given for the carbon to diffuse uniformly, there are no low-carbon areas and no triggers to start the reaction. The higher the temperature above Ac_3 the more quickly the carbon will diffuse uniformly, and if it were not for the grain growth of austenite at high temperatures in carbon steels, high temperatures might be more generally used for quenching. Of course, the temperature must be high enough above Ar_3 so that the steel does not cool below Ar_3 during the transfer from the heating furnace to the quenching bath. In order to get all the good results without the bad ones, the temperature is held only a little above Ac_3 but for a long enough time to get uniform carbon

distribution. It is naturally easiest to get uniform distribution when there is no excess ferrite or cementite to be absorbed in the range between Ac_1 and Ac_3, i.e., where there is no range and Ac_1 coincides with Ac_3, at the eutectoid composition. Eutectoid steel hardens at a lower cooling rate than do steels either higher or lower in carbon, because of the great uniformity of the austenite formed from the intimate mixture of ferrite and cementite in pearlite with no excess of either ferrite or cementite.

Similarly, in any given composition of steel, when excess of ferrite or cementite is present, the most readily hardened is the steel which is initially most uniform and fine-grained so that carbon diffusing in austenite, has only a little way to go for uniform diffusion. Hence, forging the steel and thus breaking up the grains produces a steel that hardens much more readily than the initial ingot or casting. Also a preliminary normalizing to refine the grain will make subsequent hardening by quenching easier.

Theoretically, by still further increasing the rate of cooling we should be able partly to avoid the formation of martensite and to retain some unchanged austenite, and finally to retain all austenite. Such conditions do occur in alloy steels. With carbon steels, however, only small amounts of austenite are retained on quenching at the fastest obtainable rates. As compared to martensite, austenite is relatively soft and weak.

Troostite is nowhere near so hard as martensite, and it is evident that for full hardening on quenching, martensite is the material we need. Primary troostite does not call for much consideration in the study of the principles of heat treatment, as in most heat treatment by quenching and tempering the object is first to produce as much martensite as possible and then to break this down to the required degree. Hence, primary troostite only comes into consideration as softer spots on the surface of a piece where scale or other influences have slowed down the rate of cooling below that necessary to produce martensite, or towards the center of a piece which has been so quenched that only the outside was cooled at a rate sufficient to give martensite.

The Mass Effect

If the rate of cooling at the center of a piece is too slow (See Fig. 13), obviously we will get troostite instead of martensite,

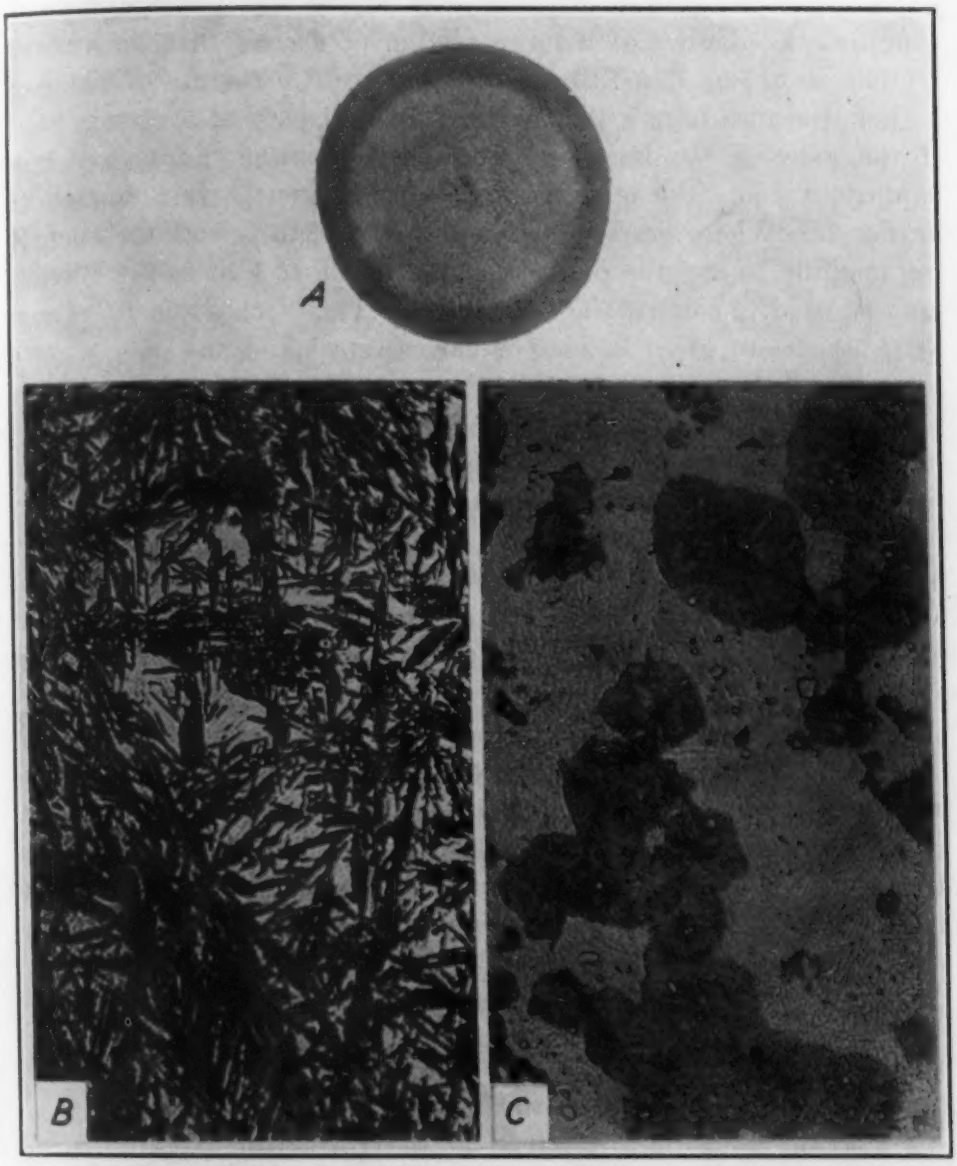

Fig. 13—(a) "Mass Effect," Which Influences the Depth of Hardening in 1.1 Per Cent Carbon Tool Steel. × 1. This Shows a Cross-Section Through 1½-Inch Round Bar of Tool Steel Quenched in Water. Only the Dark Outer Ring Attained Maximum Hardness. In the Interior the Rate of Cooling was not Fast Enough to Fully Harden the Steel. A ½-Inch Round Bar Might Have Hardened All the Way Through. Etchant, Hot 1:1 Hydrochloric Acid. (b) Appearance of Martensite. × 500. The Black Needles are Martensite. The Coarse Grain—Very Detrimental but Striking in Appearance, is Due to the High Quenching Temperature that Was Used; Namely, 1250 Degrees Cent. (2285 Degrees Fahr.). The White Patches in the Background are Austenite. The Steel is a 1.1 Per Cent Carbon Tool Steel. Etchant, Hot Alkaline Sodium Picrate. (This Etchant Colors Martensite. Dark.) (c) Martensite and Troostite. × 500. The Light Constituent Showing Needle Like Markings is Martensite. The Dark Constituent with Rounded Outlines is Primary Troostite. Small Particles of Cementite are Also Present. The Steel is 1.1 Per Cent Carbon Tool Steel. Etchant 5 Per Cent Picric Acid in Alcohol.

or if it is still slower, we will get ferrite and pearlite instead. Complete hardening of a large section of a steel that, in a small section, would harden fully in oil, may require the use of water or brine. Because heat will flow through steel only at a certain rate, if the piece is too large, no quenching medium, no matter how rapidly it cools the outside, will cool the center fast enough to harden it. Where permissible, hollow boring to permit the quenching medium to cool the piece from the inside as well as the outside, may be used to combat the mass effect. This "mass effect" cannot be overcome in great masses of carbon steel and the only way to secure hardening to the center is to use some alloy steel which does not require so rapid a rate of cooling to produce martensite.

The important rate of cooling is the rate through the temperature range that corresponds to Ar_1 on slow cooling, i. e., at about 1300 degrees Fahr. One gets a faster rate at the center of the piece at this temperature if the steel has previously started to cool on the outside, i.e., if it is quenched from somewhat above that temperature. Use of that aid to hardening (higher quenching temperatures) is limited because of the grain growth due to overheating.

As the carbon content increases up to the eutectoid, hardening is easier, i. e., a slower cooling rate will produce martensite. Increasing the cooling rate, hence acts much like increasing the carbon content. Control of cooling rate in quenching is exercised by changing the quenching medium.

Quenching Media

Various liquids have different speeds of cooling and so impart different degrees of hardness to steel on quenching.

The following data obtained at the Bureau of Standards, indicates the relative cooling velocities that may be expected with the various liquids:

Quenching Medium (not stirred or circulated)	Ratio of Cooling Rates at the Center of ½ in. × 2 in. cylinders of 0.95 per cent carbon steel taken at 720 degrees Cent. (1330 degrees Fahr.)
Water at 70 degrees Fahr. (20 degrees Cent.)	1.00
Water at 100 degrees Fahr. (40 degrees Cent.)	0.67
Water at 140 degrees Fahr. (60 degrees Cent.)	0.46
Water at 165 degrees Fahr. (80 degrees Cent.)	0.24
Water at 210 degrees Fahr. (99 degrees Cent.)	0.08

Quenching Media (continued)

5 per cent solution of brine (sodium chloride at 70 degrees Fahr.)	1.16
20 per cent solution of brine (sodium chloride at 70 degrees Fahr.)	1.00
95 per cent ethyl alcohol at 70 degrees Fahr.	0.10
5 per cent solution of sodium hydroxide at 70 degrees Fahr.	1.19
20 per cent solution of sodium hydroxide at 70 degrees Fahr.	1.21
Vegetable oils at 70 degrees Fahr.	0.15 to 0.36
Mineral oils at 70 degrees Fahr.	0.21 to 0.44
Animal oils at 70 degrees Fahr.	0.19 to 0.35

Temperature of Cooling Bath

Differences in the temperature of the bath will affect the actual hardening and physical properties of the quenched articles. In general, an increase in temperature of an aqueous solution reduces the cooling speed of the bath. This change is smaller in the temperature range 70—110 degrees Fahr. than at temperature approaching the boiling point. Most oils show relatively small changes in cooling speed with temperature. Up to 125 to 150 degrees Fahr. however, there are some oils that show real changes in cooling properties with a comparatively small variation in the temperature of the bath. The bath should be maintained near a constant temperature for consistent, uniform results in hardening. Cooling coils of various designs may be used for maintaining the bath at a constant temperature. The amount of liquid should be sufficient in relation to the size and number of the pieces to prevent an appreciable increase in temperature of the bath.

Forcing large volumes of a quenching medium such as water or brine against the work under high velocity as in a high pressure spray striking the piece from all sides, increases the rate of cooling so that very low carbon steels, which do not harden on bath quenching, may be considerably hardened. Bolts of 0.09 per cent carbon steel are thus regularly being given a tensile strength of 160,000 pounds per square inch in production.

The profound effect of the rate of cooling may be seen from the following results for small specimens of 0.21 per cent carbon steel quenched into different media and not tempered:

	Tensile strength per square inch pounds
Iced brine	235,000
Cold water	215,000
Oil	175,000
Air	85,000
Furnace Cooled	80,000

Nature of Martensite

Martensite is a key material in quenching and tempering. Martensite has occupied the attention of metallurgists for thirty years or more, and it is still difficult to say just what it is. We know how to produce it, we know its properties, and we know something about its constitution, but not all. The state of knowledge of the nature of martensite is quite comparable to that of electricity. Either one is difficult to define exactly.

The bulk of metallurgical opinion, at present, indicates that martensite is quite certainly alpha iron in extraordinarily small crystals, from which the needle-like structure is built up. The condition of the carbon is less certainly known. It appears to be present immediately after quenching as elemental carbon, very finely divided, which is eager to combine with iron to form iron carbide (cementite), and it does this so readily that it is difficult to tell when and whether it is there as carbon or as carbide. Martensite that has stood for a few hours at room temperature probably contains much of its carbon as carbide, i.e., cementite.

The cause of the extreme hardness of martensite is even more in dispute than its constitution. The extremely fine size of the alpha iron crystals, their probable distortion due to change of volume on formation, and the effect, according to the "slip-interference" theory of hardening, of the tiny particles of carbon or cementite, are all given as causes and all probably play a part. But while a better understanding of the nature of the hardness of martensite would be an aid in clarifying the principles of heat treatment by quenching and tempering, most of the mechanism involved can be followed without worrying too much about why martensite is hard.

The importance of the carbon content in the production of martensite and in the properties of martensite is obvious when we remember that ordinary water quenching does not greatly harden steel containing less than 0.15 per cent carbon, that as the carbon

increases to about 0.50 per cent the maximum obtainable hardness, with readily obtainable quenching rates, steadily increases. Increase in carbon above 0.50 per cent does not greatly affect the maximum obtainable hardness in small pieces.

We have seen (1) that martensite is hard, and (2) that a definite (or "critical") rate of cooling is required to produce it. Two other important facts about martensite affect heat treatment problems. (3) Steel expands on changing from austenite to martensite, and (4) martensite can be altered by heating, i.e., by tempering.

Expansion and Contraction of Steel

When a previously annealed steel is heated it expands at a uniform rate until the Ac_1 temperature is reached. As alpha iron (ferrite) changes into gamma iron (austenite) the steel shrinks in size because the gamma form is more dense than the alpha. When the change to gamma has been completed (end of Ac_3) the contraction ceases and the gamma in turn expands. Hence the critical ranges may be determined by measuring (with a "dilatometer") the change in size of a specimen at different temperatures as well as by observing the halts in the heating curve. (See Fig. 8B.)

If heating is carried on at too rapid a rate below Ac_1 so that the outside heats before the inside, the outside of a piece of steel may expand so rapidly as to crack away from the inside which is not expanding so rapidly. Hence when heated in a lead bath, for example, the steel is sometimes first heated slowly before being immersed in the hot lead, otherwise the immersion of a cold piece in the hot lead would tend to split the outside away from the inside because of the difference in expansion.

A bar of steel, resting on the furnace bottom and heated rapidly from the top and sides and very slowly from the bottom, will warp due to uneven expansion. A piece of steel with a heavy and a light section (especially if there is a sharp corner, not well filleted, between the two) may crack on rapid heating from unequal expansion. Unequal cooling, even in annealing may cause warping. Slow and uniform heating, especially of large or complex specimens, is therefore a very necessary precaution.

The difference in expansion as the steel passes through the critical range on heating, if all parts do not pass through this

temperature at just the same time, would lead to rupture, just as differences in rate of expansion at lower temperatures tend toward rupture, were it not that the steel, by the time it reaches the critical temperature, is so soft and plastic that it can give under the expansion and contraction stresses.

On slow cooling through the Ar range we find the reverse of what we found on heating, the steel expands as the iron changes from gamma to alpha. Since the steel is relatively soft at that range of temperatures slow cooling does not tend to crack or warp the steel. But when we quench, thus preventing the gamma iron from changing to alpha iron at Ar_1 and retaining the gamma iron, (i. e., austenite) down to the much lower temperature of Ar″ at which austenite changes to martensite, the steel is much more rigid and less able to stand the stress of unequal expansion and contraction.

Since martensite contains alpha iron which is less dense, i. e., has greater volume, than gamma iron (austenite), we would expect the steel to expand on hardening, as it changes from austenite to martensite on quenching. This is the case. Martensite of a given carbon content, indeed, is less dense than the mixture of ferrite and pearlite in an annealed steel of the same carbon content. Steel therefore expands on quenching.

Before the austenite-martensite change takes place the steel is contracting, as it cools. As soon as the outside has changed to martensite and continues to cool, it, of course, keeps on contracting. But between the end of the contraction of cooling austenite and the beginning of the contraction of cooling martensite there is a large expansion. A large section, which does not harden throughout, may therefore have very complex stresses within it during quenching. The core which has not been cooled rapidly enough to avoid that change has changed to ferrite and pearlite at Ar_1 and this core expands during Ar_1 while the outer layer, still austenite, is contracting as it cools. After that expansion is over, the core (ferrite and pearlite) and the outside (austenite) contract at slightly different rates. As the steel passes through Ar″ the outside changes to martensite and expands. This expansion tends to give the underlying austenite at the inside of the outer layer more room, and that tends to help the under layer to change to martensite, since changes in pressure have some effect upon the

transformation and hence have to be considered in a detailed study of hardening. However, the presence of austenite within the martensite matrix of normally hardened tool steel is often encountered and this appears to be due to the pressure developed when austenite transforms against a surrounding martensite network during the latter part of the hardening transformation.

Cracking of Quenched Steel

If we quench a steel plate, it is likely to split in the middle into two plates, each warping away from the center plane. This is due to the expansion when martensite is formed. Any sharp corner or any slag pocket or other inclusion within the steel acts like a wedge and a crack may start from such a place where the internal stress due to uneven expansion may concentrate. Hence great care is required in hardening complex shapes, and clean steel free from slag or other non-metallic inclusions is needed. Quenching cracks produced in a splined shaft are shown in Fig. 8A.

The quenched piece may not crack at once, when taken from the quenching bath, but may crack as it cools still further, or may even crack after several days or still longer periods of storage. This is probably partly the result of internal stress set up by uneven expansion during quenching and partly of the volume change due to the carbon disseminated in the freshly formed martensite changing over to iron carbide. The stress may be so nearly equal to the strength of the steel that the steel does not crack, as long as it is able to yield plastically to the slightest degree, but when it cools still further and stiffens still more, it will crack, or it will crack when the stress has acted long enough.

It is to avoid such cracking that it is necessary to transfer the quenched steel to the tempering bath before it gets fully cold. If it is taken out just as soon as it has passed Ar″ and the martensite has formed but before it has cooled farther, and is immediately reheated for tempering, the increased plasticity of the steel at tempering temperatures allows a release of the internal stress. If it is impossible to transfer the warm piece directly to the tempering furnace, it may help to keep it in boiling water until it can be tempered.

Allowing fully quenched pieces to remain over night before tempering is likely to result in a large proportion of cracked work.

Similarly, if any straightening of the quenched piece is required after hardening, it must be done at once, while the steel is still warm, and the straightened piece tempered immediately afterwards.

The expansion, as austenite changes to martensite, and the resulting difficulties in warping and cracking explain why large pieces like locomotive forgings are not heat treated by quenching and tempering, and why the hardening of even a small forging die in which sharp corners occur is one of the most difficult of heat treating jobs.

Similarly, the liability to cracking when a cold chisel or a rock drill is hardened at the tip only is connected with the difference in expansion and contraction of the hardened and unhardened parts. On account of the change of volume in hardening, the way a piece of steel is immersed in the quenching bath may govern its propensity toward cracking and warping. A cylinder lowered horizontally, so that the lower side hardens before the upper, will tend to warp or crack, while if lowered vertically, so that the expansion stresses are balanced about the axis, it will not be so likely to warp or crack.

Localized Hardening

"Localized hardening," in which only part of a piece of steel, as the tip of a cold chisel, is to be hardened and hence only that part is plunged into the quenching bath, is very prone to produce cracks at the junction between the hardened and unhardened parts. Moving the piece up and down during quenching will help to prevent cracking due to difference in expansion.

The rate of cooling is sometimes regulated by plunging the piece into water for a few seconds, then into oil or vice versa, or by floating a layer of oil on the water. Such hardening methods are difficult to control.

Where tool steel die blocks are face-hardened it is important to have the bath agitated so as to avoid a sharp water line. This is usually done by running compressed air into the bath or by playing a water jet on the face of the die. Where jet quenching is employed it is good practice to construct the nozzle so that the water will have a centrifugal action. This is often accomplished by drilling holes in a pipe on a tangent. This practice tends to avoid minute steam pockets and non-uniform hardness.

CHAPTER V

TEMPERING

Instability of Martensite

Although martensite can exist unchanged at ordinary temperatures for thousands of years, as is shown by ancient cutting tools still in existence, it is not stable above about 375 degrees Fahr. Heating at temperatures above that at which martensite begins to break down is called *tempering*. The term "drawing the temper," or simply "drawing" is very often used but the term "tempering" is preferred. The longer the time at this temperature or the higher the temperature, the more rapid is the change, till at 600 degrees Fahr. the change is completed in a few minutes. Hence carbon steel cutting tools, such as engraving tools in which it is desired to retain all the martensite on account of its hardness and strength, should not be tempered above 375 degrees Fahr. if maximum hardness is to be retained. The internal stresses arising from expansion due to the formation of martensite can be considerably relieved by heating to 350 to 375 degrees Fahr. for an hour or more, per inch of thickness.

Since steel is seldom, if ever, 100 per cent martensite after quenching, but, instead, generally contains small amounts of austenite or of primary troostite along with the martensite, depending on the quenching rate used, it is possible for a steel to become harder on tempering, since the austenite may go over to martensite during tempering.

The pressure relations existing during the first stage of tempering appear to accelerate the decomposition of martensite. From the dimensional changes on tempering, it was observed that the initial contraction (first stage) is greater with water quenching than with oil quenching and with a high quenching temperature than with a low, while the final contraction (third stage) was little affected by these variables.

The belief is forming nowadays that, while freshly quenched martensite consists of alpha iron plus free carbon that has been thrown out of its previous solid solution in gamma iron (or is perhaps held in a sort of "forced" or unstable solid solution in the alpha iron), the carbon on standing, or aging, combines with

some of the alpha iron to form iron carbide, cementite, and, of course, this combination progresses more rapidly on heating.

Secondary Troostite

As martensite is heated between 375 and 550 degrees Fahr. it is changed into *secondary troostite,* a constituent rather similar in properties to the primary troostite which is formed on quenching at a rate slightly less rapid than that which gives martensite. Secondary troostite is not so hard as martensite and very much tougher. It, like martensite, contains alpha iron, but the carbon in troostite is quite certainly present as finely divided iron carbide (cementite). Hence, when it is desired to combine hardness and toughness, the tempering time and temperature are so regulated as to produce some troostite. The proportions desired will depend on the service to which the steel is to be put. Tools that have to stand battering, as a cold chisel, are tempered to produce considerable troostite. A spring, in which not only great strength but toughness as well is needed, will be tempered at around 600 degrees Fahr. or even higher, so as to be principally troostite. The change in structure on tempering is shown in Fig. 14.

Temper Colors

The degree of tempering can be roughly told by the color of the film of oxide formed on a clean surface when the steel piece is heated in the air. The thickness of the film and hence its color depends on both time and temperature, much as the softening of the steel does, so that the "temper colors" (given at the lower right side of the conversion scale of Fahrenheit (Fahr.) to Centigrade (Cent.) degrees, Fig. 15), give a rough approximation of the softening that has taken place.

This visual indication varies with the steel, and is only a very rough one and therefore not a satisfactory substitute for a pyrometer in accurate work.

Sorbite

If we heat either primary troostite or secondary troostite above about 550 degrees Fahr. it, in turn, changes into still another microconstituent, recognizable under the microscope and called "*sor-*

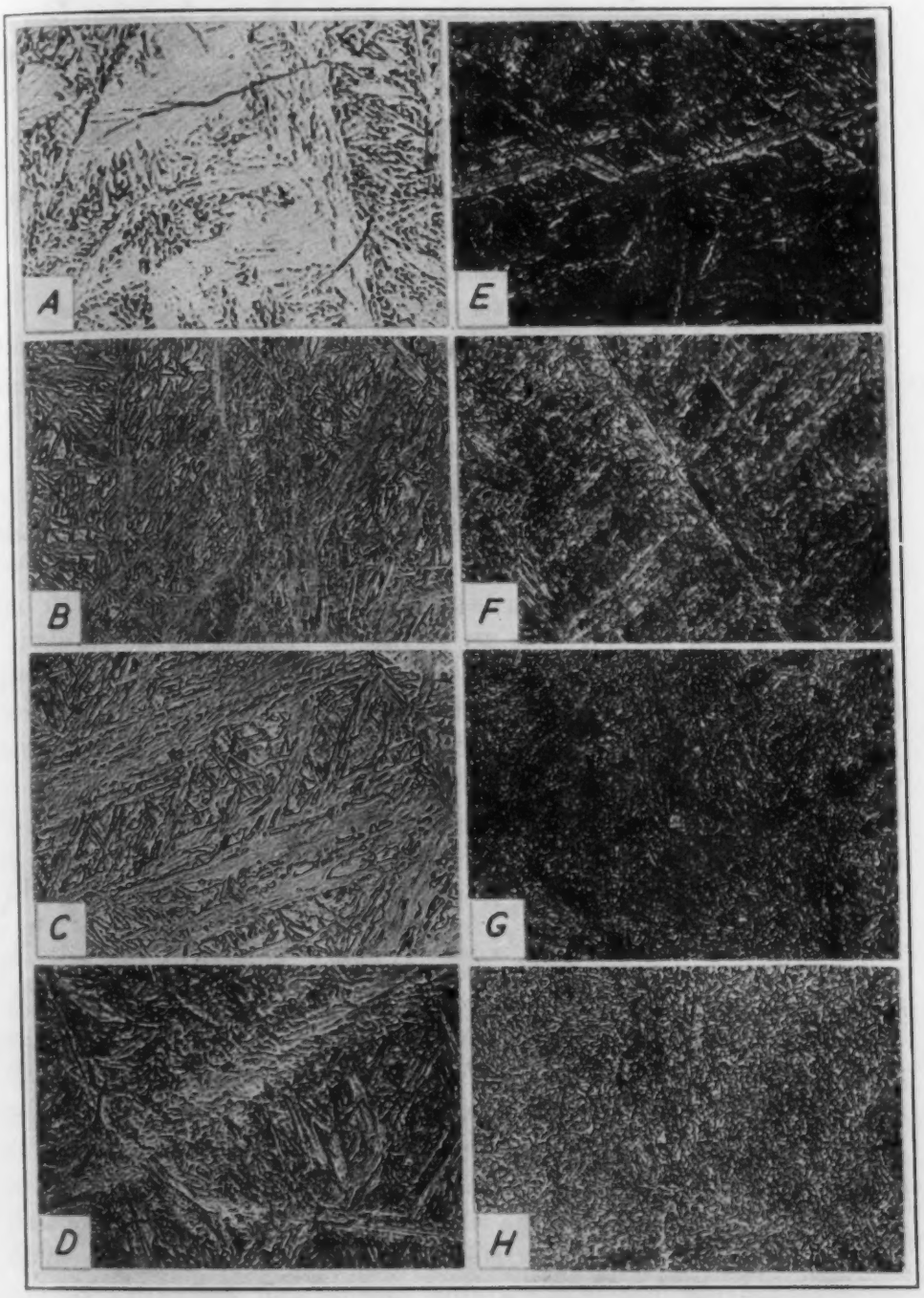

Fig. 14—Effect of Tempering Upon the Microstructure of 1.1 Per Cent Carbon Steel Quenched in Water from 1150 Degrees Cent. (2100 Degrees Fahr.). × 500. After Quenching the Structure is Martensite with Some Austenite. After Tempering at 245 Degrees Cent. the Austenite is Decomposed to Martensite, and at 300 Degrees Cent. and 400 Degrees Cent. Secondary Troostite Appears; This Etches Much Darker than Martensite. After Tempering at High Temperatures (500 Degrees Cent. and 600 Degrees Cent.) the Structure is Sorbitic. (a) Untempered. (b) 100 Degrees Cent. 20 Days. (c) 200 Degrees Cent.—4½ Hours. (d) 245 Degrees Cent.—4½ Hours. (e) 300 Degrees Cent.—4½ Hours. (f) 400 Degrees Cent.—2¼ Hours. (g) 500 Degrees Cent.—2¼ Hours. (h) 650 Degrees Cent.—2¼ Hours.

bite." This microconstituent was named, like as for most of the above described microconstituents, for Sorby, one of the early metallurgists who advanced our knowledge of steel. It occurs, however, in two forms, that formed from primary troostite being, more strictly speaking, sorbitic pearlite instead of sorbite and that formed from secondary troostite (itself formed from martensite) being true sorbite. Both sorbite and sorbitic pearlite consist of cementite in very fine particles interspersed in ferrite.

Martensite is very hard, strong and brittle. Carbon steels with large proportions of martensite cannot be machined by usual methods; they must be ground to shape. Martensite in carbon steels will have a Brinell hardness number of roughly 625 to 425. Troostite is less hard, quite strong and rather tough. It has a Brinell hardness number of roughly about 425 to 375. Troostitic carbon steels are machinable only with difficulty. Sorbite is still less hard than troostite, less strong, but very much tougher. Sorbitic steels have greater resistance to impact than martensitic or troostitic steels. Sorbite has an extraordinarly fine-grained structure. It is the essential constituent in most heat treated steels used for automotive construction. The transition from martensite to troostite is not abrupt, but rather gradual. That from troostite to sorbite is even more gradual. Troostite starts to change to sorbite at perhaps as low as 500 degrees Fahr. so that one may readily obtain a single steel containing some martensite not yet changed to troostite, troostite, and some troostite that has changed to sorbite.

Coalesced Sorbite

Sorbite consists of ferrite and cementite, but differs from the ferrite and pearlite (which itself is ferrite and cementite) or pearlite and cementite or slowly cooled, unquenched steel in that the cementite cannot be seen under the microscope. If sorbite is heated still further, the cementite agglomerates and the steel approaches the structure of the slowly cooled steels, which contain pearlite. Strictly speaking, this structure should not be called pearlite, because pearlite contains ferrite and cementite in the definite eutectoid ratio, and sorbitic steels, on further heating, do not necessarily distribute their cementite into pearlitic patches of just that ratio plus patches of free ferrite or free cementite, depending on whether the steel is hypo or hypereutectoid. Instead,

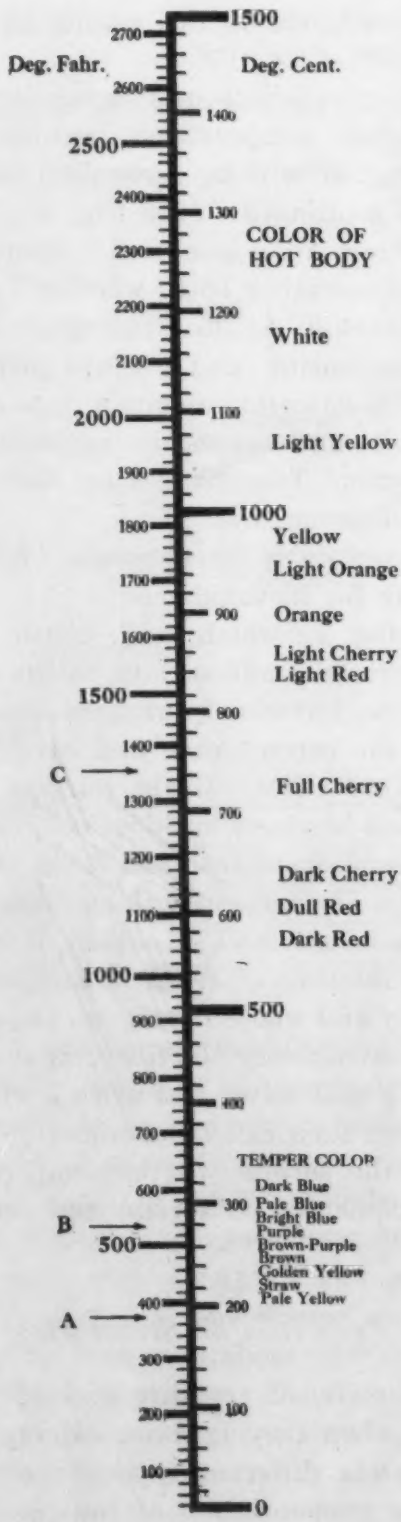

Fig. 15—Fahrenheit-Centigrade Temperature Conversion Scale, with Temper Colors (at Lower End of Scale). A. At About 375 Degrees Fahr., Martensite Begins to be Decomposed Into Secondary Troostite on Heating. B. At About 500 to 550 Degrees Fahr., Secondary Troostite Begins to Change to Sorbite on Heating. C. At About 1350 Degrees Fahr. (Ac_1) Austenite Begins to Form on Heating.

the cementite is more uniformly distributed among all the ferrite present.

Agglomeration of both the ferrite and cementite occurs on long tempering at the highest temperatures possible (i.e., just below Ac_1). This agglomeration will be recognized as the spheroidizing process previously mentioned. (See Fig. 4c).

On long heating just below Ac_1 a steel will "divorce" its ferrite and its cementite, agglomerating both, whether its austenite was originally slow cooled through Ar_1 to give pearlite or whether it was quenched to form martensite (and perhaps primary troostite), the martensite breaking down to secondary troostite, and in turn breaking down to sorbite and the sorbite agglomerating into ferrite and globular cementite. The changes on cooling and on reheating are shown in the diagram, Fig. 16.

Tempering to produce sorbite is often termed "toughening" because sorbite is noteworthy for its toughness.

The changes on tempering, by which hard, brittle martensite may be converted, through troostite and sorbite, to the soft, tough ferrite plus globular cementite, fortunately progress slowly enough so that we may, by using the correct time and temperature for tempering, stop at any desired stage. If the purpose for which the steel is to be used demands hardness but does not require much toughness, the steel is relieved from internal stress as much as possible but is left martensitic. If great strength and some ductility, i.e., a fairly hard but not too brittle steel, is needed, it is tempered to produce a good deal of troostite. Where some strength can be sacrificed for machinability and where toughness, i.e., a combination of good strength and satisfactory ductility, is needed, it is tempered to sorbite. When a still softer and more ductile (but at the same time a stronger steel than can be obtained on annealing or normalizing) is needed, the sorbite will be tempered at still higher temperatures to agglomerate its ferrite and cementite to the desired degree.

Dependence of Properties on Structure

The properties of martensite, of troostite and of sorbite all depend on the amount of carbon they contain. Hence, for each carbon content we start with a different type of each of these different constituents and by proper choice of time and tempera-

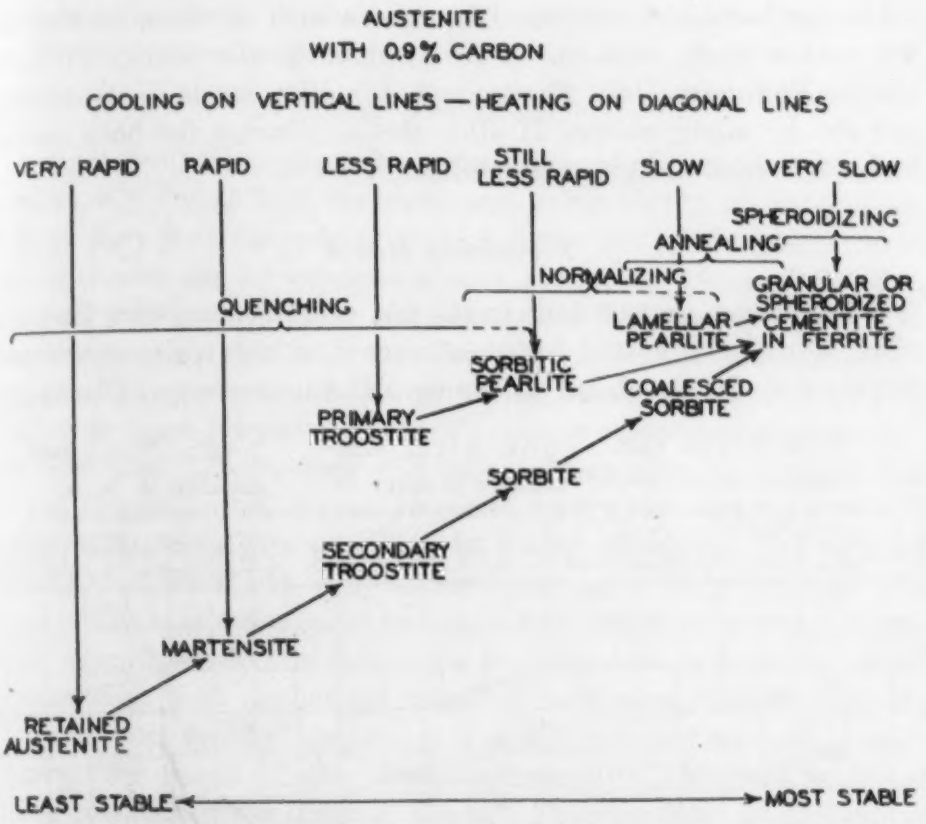

Fig. 16—Diagram Illustrating How Various Structures May be Obtained in a Eutectoid Steel by Varying the Rate of Cooling and of Reheating After Quenching. In Steels of Lower Carbon Content Excess (Proeutectoid) Ferrite and in Those of Higher Carbon Content Excess (Proeutectoid) Cementite may Separate on Cooling, as Well as the Constituents in the Diagram. Such Separation is the More Complete the Slower the Cooling. If the Austenite is not Homogeneous Before Cooling Begins, but has Different Carbon Content at Different Points, the Structure after Quenching will Vary in Different Parts Because Variation in Carbon Has Much the Same Effect as Variation in Cooling Rate.

ture of tempering, may modify the properties of each. For structural purposes, by choice of carbon content of a plain carbon steel and, through quenching to form martensite and tempering this to form troostite, sorbite or ferrite and cementite we can grade from a high carbon steel of 350,000 pounds per square inch tensile strength and practically no elongation (martensite) through a 0.50 per cent carbon steel with about 250,000 pounds per square inch tensile strength and 3 per cent elongation (troostite) down to a 0.25 per cent carbon steel with about 75,000 pounds per square inch tensile strength and 35 per cent elongation.

The mechanical properties of quenched and tempered steels are so profoundly changed by changes in time and temperature of tempering that the relationships cannot be readily expressed in

tables, and are best expressed in curves such as those in Fig. 17. For carbon steels, such curves are available in the Society of Automotive Engineers Data Sheets, and, for alloy steels, in pamphlets put out by many makers of alloy steels. Curves for both carbon and alloy steels are given by Bullens[10].

Tempering Media

Tempering may be done in the air, as by heating in a furnace, often electrically heated for close control of the temperature and the air may be circulated to improve the uniformity of tempera-

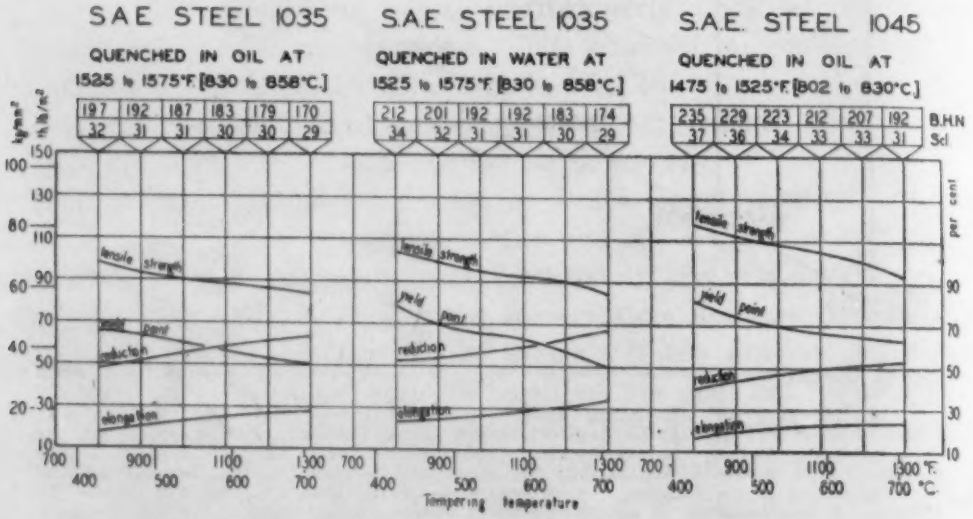

Fig. 17—Strength, Ductility and Hardness of 0.35 Per Cent and 0.45 Per Cent Carbon Steels Quenched in Oil or Water and Tempered at Different Temperatures.

ture, in molten lead (or tin-lead) baths, in fused salt baths or, for the lower temperatures, in oil.

Oil of sufficiently high flash point may be used to about 500 degrees Fahr. From 450 to 900 degrees Fahr. mixtures of sodium and potassium nitrates are largely used. Between 650 and 1250 degrees Fahr. lead baths are often used. From 1000 to 1650 degrees Fahr. various chloride mixtures are used. Above 1500 degrees Fahr. some sodium or potassium cyanide is usually added to combat the decarburizing tendency of the salt bath. Cyanide is very poisonous and great care must be used when it is employed. If a lead bath is overheated, fumes may be given off that will cause lead poisoning. Those fused salt or lead baths which will not fume or

[10]Bullens, D. K., "Steel and Its Heat Treatment," third edition, 1927.

decompose too badly at the required temperature may also be used for heating before quenching.

Self Tempering

Since tempering depends on both time and temperature, and goes on rapidly at high temperatures, more slowly at lower ones, it is evident that the *rate* of cooling below Ar″, (the point where austenite changes to martensite and hardening takes place, Fig. 12) will regulate whether the martensite will partly temper to troostite (or in a steel with a sufficiently high Ar″, even to sorbite) during the latter part of the quenching operation. If, instead of cooling to room temperature, the cooling is stopped as soon as Ar″ has been passed, tempering will occur. If an alloy steel which has Ar″ at 750 degrees Fahr. and in which a very slow cooling rate will produce martensite, is quenched in a bath of molten lead held at 650 degrees Fahr., it will be hardened on cooling through 750 degrees Fahr. and tempered on heating at 650 degrees Fahr. in the same operation. While this is an extreme case and carbon steels require such high quenching rates for hardening that the amount of tempering during quenching is small, yet self-tempering may account for much of the secondary troostite and sorbite found after quenching low carbon steels. This method is applied to carbon steel wire in which it is desired to obtain a sorbitic structure. The wire is heated above Ac_3 and then both quenched and tempered by passing it through a bath of relatively cool melted lead. This is one method of carrying out the "*patenting*" process used on music wire, etc., which is later to be severely cold-drawn and which must first be made strong by heat treatment so as to withstand the heavy drafts necessary to draw it down to fine wire. "Patented" wire of eutectoid composition after cold drawing may have a strength above 400,000 pounds per square inch.

Some metallurgists believe that austenite cannot pass directly to troostite, sorbite or even to ferrite and pearlite without first passing through martensite, so that momentary hardening followed by self-tempering is postulated to occur at any rate of cooling. The bulk of experimental evidence seems to be against this idea and it has not been utilized in preparing this outline. In attempting to normalize some alloy steels whose critical cooling rate is low, very complex structures may be obtained since, on cooling, ferrite and pearlite, primary troostite and martensite may be formed in

different parts of the specimen and secondary troostite and sorbite may form by self-tempering during cooling. In order to control the structure in such a case it is necessary to harden completely and temper in a separate operation rather than to depend on hardening and tempering in one operation for uniform results.

But when a steel is to be tempered at a temperature above its Ar″, if the steel can be withdrawn from the quenching bath immediately after Ar″ has been passed and hardening has been accomplished and at once transferred to the tempering bath or furnace, the dangers of cracking and warping during the cooling from Ar″ to room temperature can be largely avoided.

Untempered Steel

Quenching without tempering, other than self-tempering, is chiefly applied to very low carbon steels. The useful results that can be obtained, even with steels below 0.10 per cent carbon, by spray and pressure quenching, have already been commented on. Quenching in liquid baths is often applied to those steels under 0.20 per cent carbon which do not harden to martensite at the cooling rates met in such practice, i.e., do not show an Ar″ point, but which have only the normal Ar_1 or the Ar′ (troostite) points. The object of such a quenching is to secure grain-refinement similar to that of normalizing, plus the formation of a little primary troostite (which may temper to sorbite by self-tempering). The structure so obtained machines with less tearing than that of the annealed or normalized steel, and has higher toughness.

If very small pieces of the low carbon steels are drastically quenched some austenite may form, even though it may self-temper, and to eliminate internal stresses from this cause, tempering at low temperatures for stress-release is often necessary, especially with carbon approaching 0.20 per cent and with high manganese. The bulk of the toughening in these low carbon steels is, as a rule, due to a grain refinement rather than to the formation of martensite and, from it, troostite and sorbite. The addition of alloying elements may make a 0.15 or 0.20 per cent carbon steel fully hardenable, however.

Quenching without tempering at all, or quenching followed by tempering at low temperatures that is aimed only for stress-release, and not a change of structure, is also sometimes applied to carburized steel.

(To be concluded in December issue of TRANSACTIONS*)*

Educational Section

These Articles Have Been Selected Primarily For Their Educational And Informational Character As Distinguished From Reports Of Investigations And Research

THE CONSTITUTION OF STEEL AND CAST IRON
SECTION II—PART V

By F. T. Sisco

Abstract

This installment, the fifth of the present series, takes up the slip interference theory of hardening. The term hardness is discussed and is defined as resistance to permanent deformation. Next is viewed the cause for the hardness of the various constituents encountered in alloy systems namely: metallic chemical compounds, solid solutions, eutectic alloys, amorphous metal, and small grains. This discussion leads to a review of crystallization and the consideration of the planes of weakness in crystalline materials and the cause of intercrystalline slip. Following this is an elementary explanation of Jeffries' and Archer's slip interference theory of the hardness of metals.

IN previous installments the discussion of the theory of heat treatment has had as its object an understanding of the constitutional changes taking place in steel while it is passing from a less stable structural state to one that is more stable. In other words we have viewed the structural changes taking place in annealing; which in its widest meaning is a process whereby the structure, through the action of heat tends to approach a condition of stable equilibrium. All of the various processes usually included under the general term annealing are characterized by a partial or complete return to stable equilibrium. These processes include the annealing of low and medium carbon steels, the annealing of high

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This is the fourteenth installment of this series of articles by F. T. Sisco. The several installments which have already appeared in TRANSACTIONS are as follows: June, July, August, September, November, 1926; January, February, April, June, August, October, 1927; February, April, June, 1928.

carbon and alloy steels containing carbides, spheroidizing, annealing below the critical range, patenting, annealing steel castings, and the graphitization of malleable iron.

The procedure necessary in annealing includes heating to a temperature just above the critical range so that austenite is formed, followed by a relatively slow cooling; a cooling rate depending upon how stable a structure is desired. In some cases the result is attained by a more complicated operation such as heating above the critical range with a slightly accelerated cooling, followed by heating to just below the range. No matter what procedure gives us the final result most quickly or economically, the theory involved remains practically the same: namely to regulate the constitutional changes so that there will be complete, or almost complete reversion to a condition of stable equilibrium.

In hardening we go through much the same procedure, that is, heating above the critical range so that austenite is formed followed by cooling at a rate, but this time with a different objective, depending upon how unstable a structure we desire. We may attain this result by a simple heating and cooling through the range, or in some cases we may necessarily adopt a more complicated procedure but in any case we attain the desired objective —a relatively unstable structural condition; which ordinarily is accompanied by properties much different than those resulting when the material is in a stable state. We will find as we view hardening in detail that it is not always necessary to heat to above the critical range and to cool again through this range to produce this unstable condition. It is possible to work a material so severely that an unstable state results simply from that severe work. Cold drawn wire is a well known example of hardening without any thermal change taking place.

Hardness

Before taking up the structural changes that occur when steel is hardened by various methods, either by thermal treatment or by strain, it is essential that we have a clear understanding of what is meant by hardness. Hardness is a general term describing a number of specific properties. Among these properties are the strength or resistance to rupture in tension or compression, the resistance to indentation or the elasticity as measured by the

Brinell and scleroscope hardness testers, the resistance to abrasion, scratching, or to machining, and others.

Unless there is some definite property in mind, the term hardness is apt to be confusing. For example, if a piece of high carbon tool steel is heat treated by quenching in water from about 1500 degrees Fahr. it will be too hard to machine, even with the best tools. If the steel is now tested by the Brinell machine it will be found that the hardness is in the neighborhood of 600. If this piece of steel is tempered by reheating to some temperature between 1000 and 1300 degrees Fahr. it will then machine easily. The Brinell hardness will be approximately 225, probably less. Now if a piece of 14 per cent manganese steel is heated to 1850 degrees Fahr. and quenched in water it, too, will be too hard to machine even with the best tools, but if tested by the Brinell machine the hardness will be approximately 200 to 225, or the same as the carbon tool steel tempered to the point where it machines easily.

For the man who tries to machine these two quenched steels both may be equally hard, because his tools will have little or no effect on them; whereas measured by the Brinell machine the quenched tool steel is two or three times as hard as the quenched manganese steel. We can say, therefore, that the quenched tool steel has high strength, high resistance to indentation and high resistance to machining, or to abrasion by a cutting tool, while the quenched manganese steel has only high resistance to abrasion by the cutting tool.[30]

Another example of the different meanings given to the term hardness is the hardness imparted by cold work. A high carbon tool steel heat treated so that the ultimate strength will be in the vicinity of 300,000 pounds per square inch is so hard that it cannot be filed nor machined. A piece of medium or high carbon steel may be cold drawn so that it has a strength of 300,000 pounds per square inch but this steel can be easily filed and easily machined.

Speaking precisely from a metallurgical viewpoint we can now define hardness as the resistance of a metal to permanent deformation.

In the following discussion of hardening we will treat first of all the general concept of the hardening of metals. From that we

[30]The ultimate strength of quenched manganese steel is in the neighborhood of 100,000 pounds per square inch while quenched tool steel is nearly 300,000 pounds per square inch.

will pass on to the hardening of steel by thermal treatment, in other words by quenching and tempering. This completed, the next step will be a discussion of strain hardening or the hardness imparted by cold work and finally the explanation for the hardness of such materials as high nickel and high manganese steels.

In order to prevent confusion in terminology the terms "hard" and "hardness" in their application to steel will denote an unstable structural condition whereby through the action of heat the material has high resistance to rupture in tension, in other words a high tensile strength, a high resistance to indentation recognizable by a high Brinell hardness number and great resistance to machining. The term "strain hardening" or "strain hardness" will apply to that structural condition and the accompanying high tensile strength resulting from cold work. The hardness of such materials as high nickel and high manganese steel will be described by the term "austenitic hardness."

General Causes of Hardness

In an early installment of the first series we discussed the crystallization of metals and saw that in general, when a metal or an alloy of two or more metals solidifies from its melt, the atoms tend to arrange themselves in definite geometrical patterns. The aggregate of a large number of atoms so arranged is known as a crystal. The atoms making up a crystal are held in their atomic position by strong forces. These forces are of two kinds: attractive forces and repulsive forces. The attractive forces tend to resist the permanent deformation or rupture of the metal in tension and the repulsive forces tend to resist the permanent deformation or rupture of the metal by hydrostatic forces in compression.

The failure of metal by rupture, or, in fact, any permanent deformation in a metal, takes place when the stress applied becomes so much greater than these atomic forces that the interatomic bonds are broken. In crystalline materials there are present planes of weakness commonly known as slip planes. When a metal or metallic alloy fails it is usually due to a stress of such magnitude, or applied in such a manner that aggregates of atoms move along these slip planes until permanent deformation or actual rupture occurs.

If hardness is defined as the resistance of a metal or metallic

alloy to permanent deformation and since it is well known that rupture, or permanent deformation at least, takes place by the movement of atom aggregates along planes of easy slip, it is quite evident that anything which will increase the resistance of these aggregates of atoms to relatively easy gliding along these slip planes will increase the hardness. The general cause of hardness is, therefore, resistance to slip.

Starting with the fact that pure metals are inherently soft and ductile, and that planes of weakness or easy slip are characteristic of the crystallization of these pure metals, Jeffries and Archer[31] advanced the brilliant theory that hardness is due to interference with slip. .

In the discussion of the constitution of alloy systems in an early installment of the first series[32] we saw that when two or more metals are melted and mixed either of three conditions may be the result: the molten metals may be completely insoluble in each other, they may be completely soluble in each other, or they may be partially soluble in each other. In the solid state the same conditions may prevail. We have, therefore, in alloy systems of two or more metals: 1. The solid solution, 2. The eutectic alloy, or both. In addition a metal may react with another metal or with a nonmetal to form a chemical compound and this compound, in turn, may be completely soluble, completely insoluble or partly soluble in the metal or metallic alloy in the solid state.

In discussing the causes of interference to easy slip, it will be necessary to view the hardness of a chemical compound, the hardness of a solid solution, and the hardness of a eutectic alloy; and the effect of these on the resistance of a metal or alloy to slip.

The crystalline state is not the only one that may be present in a metal or metallic alloy. Occasionally due to strain, undercooling or some other cause, the amorphous state may exist. Amorphous metal is characterized by a haphazard arrangement of the atoms; they do not fall into definite and repeating geometrical patterns as occurs in crystallization. In discussing the cause of hardness or interference to slip, we must take into consideration the fact that amorphous metal may be present or may be formed and consequently may be a factor in the hardness.

[31] *Chemical and Metallurgical Engineering*, Vol. 24, No. 24, 1921, p. 1057. See also their book, "The Science of Metals." The McGraw-Hill Book Co., 1924.

[32] TRANSACTIONS, American Society for Steel Treating, Vol. 10, p. 267, August, 1926.

Another factor that may enter into slip interference is grain size. It is well known that the size of the crystalline grains has a great influence on the properties of the metal. Thus a discussion of hardness or slip interference must consider the size of the individual crystal unit or grain.

It is plain, therefore, that the hardness of a metal or metallic alloy, in other words the resistance to slip, may be increased due to the influence of one or more of these five factors, which, inherently or because of some effect they have on the metal increase the hardness. These five factors are: 1. the chemical compound, 2. the solid solution, 3. the eutectic alloy, 4. amorphous metal, and 5. the grain size.

Hardness of Chemical Compounds

An inherent characteristic of the chemical compounds found in metals or metallic alloys is their great hardness and brittleness. We only need to cite the well known compound of iron and carbon, Fe_3C, and of copper and aluminum, $CuAl_2$, as evidence. The strength of iron carbide, Fe_3C, has in the past been put at a relatively low figure; for example Sauveur gives a strength of 5000 pounds per square inch but questions the accuracy of this figure. He also states that Fe_3C is as hard and as brittle as glass. Jeffries, on the other hand, states that the true strength of Fe_3C is several hundred thousand pounds per square inch. There is no question as to the great hardness and brittleness of Fe_3C; this is evident from its effect on the iron-carbon alloys, especially noticeable in the white cast irons.

The hardness and strength of the commercial aluminum-copper (duralumin) alloys is due to the presence of the metallic compound, $CuAl_2$. The Brinell hardness of pure aluminum is about 25 and of pure copper about 40, but for the chemical compound $CuAl_2$, Jeffries assigns a hardness value of 300. The addition of a small amount of copper to pure aluminum increases the Brinell hardness to nearly 90 for the heat treated 4 per cent copper alloy. The brittleness of $CuAl_2$ is well known from its use in the manufacture of aluminum alloys. A hardener containing 50 per cent aluminum and 50 per cent copper is almost wholly $CuAl_2$. This alloy is useful in the foundry not only on account of its low melt-

ing point but also because of its brittleness; it can be broken easily into small pieces.

Such metallic compounds as Fe_3C and $CuAl_2$ are hard for two reasons: first, because of the unusually high attractive forces assumed to exist in the atoms, and second, because their crystals are exceedingly complex and do not have present the many slip planes characteristic of pure metals.

Hardness of Solid Solutions and Eutectic Alloys

When one metal is in solid solution in another metal the hardness and strength are increased. A well known example of this is the higher strength and hardness of a common brass over pure copper. Assuming that there is no change in hardness due to a difference in grain size or for other reasons, the addition of about 30 per cent zinc to copper increases the tensile strength from 30,000 to 45,000 pounds per square inch and the Brinell hardness from 35 to 55 or about 50 per cent.[33] In general the hardness and strength of a solid solution increases progressively with increasing percentages of the solute metal until it reaches a maximum at about 50 atomic per cent. This increasing strength and hardness is evident in the alpha brasses in which the strength increases progressively as the percentage of zinc increases up to the limit of solubility which is about 37 per cent zinc.

Several explanations have been advanced for the increased hardness of solid solutions over the hardness of the solute and solvent metals. Rosenhain maintains that the introduction of solute atoms distorts the space lattice of the solvent metal in various ways and so increases the resistance to slip. Jeffries and Archer claim that the increased resistance to slip is due only partly to the distortion of the lattice by the entrance of "stranger" atoms: mostly, however, it is due to a greater attraction between the unlike atoms of the solid solution than between the like atoms of the pure metal.

In general the properties of a eutectic are closely related to the properties of each of the constituents making up the alloy. Increased strength and hardness of a eutectic are due principally to the fact that in general eutectics are fine grained. This is

[33] Cited in Jeffries and Archer—The Science of Metals, 1924, p. 255.

more properly a question of grain size than it is of any inherent characteristic in the eutectic itself.

Hardness of Amorphous Metal

As has been noted crystallization is characterized by an orderly arrangement of the atoms in definite and repeating geometrical patterns. When the atoms or molecules are spaced haphazardly, and do not follow an orderly arrangement the material is amorphous. Although most metals crystallize when solidifying from their melt, under certain conditions it is possible for amorphous metal to be formed. Amorphous solids are in truth fluids of very high viscosity. This is evidenced in the case of glass. This amorphous material, although very hard and brittle at atmospheric temperature, will under certain conditions flow in a manner analogous to a fluid. If a long rod of glass is supported at each end it will sag appreciably in the center in a few months. It is a well known characteristic of amorphous materials that they soften over a long temperature range before they become actually fluid.

As amorphous metal is characterized by a haphazard arrangement of the atoms or molecules, it is clear that there can be no planes of weakness or easy slip, such as occur in ductile crystalline materials. It follows from this that in the amorphous state and so long as the temperature is low a material will be harder and stronger than a material in the crystalline state. Should the amorphous material be subjected to heat, however, it may soften to the point where it is much weaker than a crystalline material.

The role of amorphous metal in increasing the hardness and strength of the iron-carbon alloys at low temperatures is an important one. The amorphous metal theory first advanced by Beilby is one which has aroused much controversy in recent years especially since the appearance of the slip interference theory of Jeffries and Archer. We shall discuss the role of amorphous metal in more detail when the theories of the hardening of steel are taken up in a later installment.

So far as the hardness and strength of amorphous metal are concerned we can sum this up briefly by quoting Beilby's own words: "The development of the maximum intrinsic hardness of the metals can thus be brought about in many different ways, but

in every case it appears to depend on the special development of the cohesive forces which are associated with the amorphous or noncrystalline aggregation of the molecules."

Hardness Due to Small Grains

A bar of metal consisting of a large number of small grains is harder and stronger than a bar of the same metal made up of a small number of large grains. The reason for this is clear. In a bar of metal made up of a small number of very large grains there are likely to be some continuous planes of easy slip. On the other hand in a bar of metal made up of a large number of very small grains, the orientation of these many grains will be extremely haphazard, consequently there is little likelihood of there being any continuous planes of weakness. When slip starts in one grain it cannot continue into a neighboring grain without change of direction. Permanent deformation is thus stopped or at least hindered at the grain boundaries. If many very small grains are present there will be many grain boundaries and frequent change in the direction of slip.

If we assume that there is amorphous metal at the grain boundries, a material having many small grains will contain a much greater total amount of this amorphous metal than one in which large grains are present. As this amorphous metal is no doubt a fluid of high viscosity and as at low temperatures it is very hard and strong, it contributes to the total strength of the small-grained material.

The reason that a fine-grained material is harder and stronger than a course grained material is, therefore, because: first, with many grains continuous planes of easy slip are not so likely to be present as when just a few grains are present; and second a fine-grained material will contain a larger total amount of hard amorphous metal than a coarse grained material.

Sykes[34] in his work on the relation between grain size and strength gives the following results for molybdenum wire.

	Tensile Strength, Pounds Per Square Inch
Single Grain	32,000
Average grain diameter of 0.0011 inches	51,000
Average grain diameter of 0.0002 inches	96,000

[34] Effect of Temperature, Deformation, Grain Size and Rate of Loading on the Mechanical Properties of Metals. American Institute of Mining and Metallurgical Engineers, Feb., 1921.

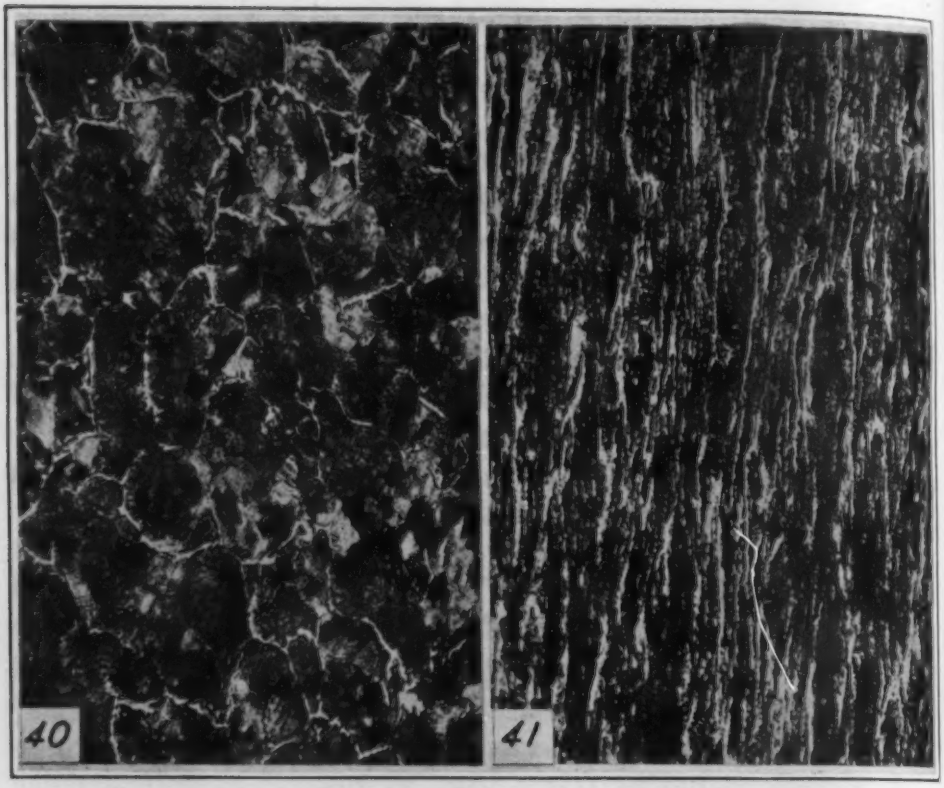


Fig. 40—Equiaxed Grains in 0.45 Per Cent Carbon Steel. × 500. Etched in Alcoholic Nitric Acid.

Fig. 41—Elongated Grains in 0.45 Per Cent Carbon Steel Due to Permanent Deformation. × 500. Etched in Alcoholic Nitric Acid.

An example of the strength due to small grains familiar to all steel men is the strength of cold-drawn wire. Cold drawing breaks up the original grains into small fragments and ultimately produces a more-or-less haphazard orientation resulting in few if any continuous planes of easy slip.

Intercrystalline Slip in Pure Metals

In a cast and slowly cooled, or annealed metal, the crystalline grains tend to assume a regular equiaxed form. Now if a stress is applied to these equiaxed grains they tend to elongate; for example in the drawing of wire the grains are elongated from an original form such as shown in Fig. 40 to the form shown in Fig. 41. This permanent deformation takes place by means of the movement of the atom aggregates along planes of easy slip.

Jeffries and Archer have described the mechanism of inter-

crystalline slip so well and clearly that we can do no better than make use of their illustration.[35] Fig. 42 depicts a crystal of a pure metal with the horizontal lines representing planes of easy slip. Suppose now that instead of this illustration representing a crystal, it represents a stack of steel plates, put together so that they make a pile in the form show in Fig. 42. Suppose further that this stack of steel plates is placed in a strong magnetic field

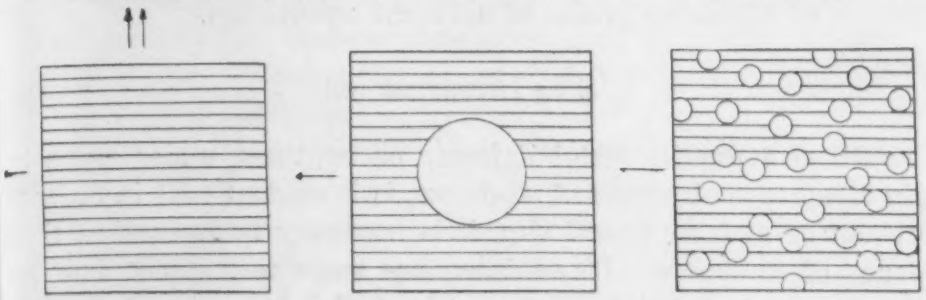


Fig. 42—Crystal Having No Hard Particles. Fig. 43—Crystal Having One large Hard Particle. Fig. 44—Crystal Having Many Small Hard Particles.

which is at right angles to their plane surfaces. The plates are magnetized and are held tightly to each other. Suppose we apply a stress in the direction of the double arrows. A tremendous force would have to be applied to overcome the magnetic force which holds the plates together in order to pull the stack apart. Now suppose we apply a stress in the direction of the single arrow. A slight pull would cause the plates to slip along their plane surfaces. This simple experiment which can be performed with two small pieces of magnetized iron or steel illustrates clearly the mechanism of slip along the planes of weakness in a metallic crystal.

When slip occurs there is apparently a partial disruption of the interatomic bonds. Frequently, however, after slip has started it stops and if the stress is continued starts anew on some other plane. The cause of this stoppage of slip in pure metals is not known definitely. That there is a partial re-establishment of atomic cohesion is certain. The stoppage may also be explained by the formation of hard amorphous metal due to the rubbing action of one crystalline particle on another. Jeffries and Archer[36]

[35]The Slip Interference Theory of the Hardening of Metals, *Chemical and Metallurgical Engineering*, June 15, 1921, p. 1061.

[36]The Amorphous Metal Hypothesis, *Chemical and Metallurgical Engineering*, October 12, 1921, p. 703.

say that it is probable that only a small percentage of slips are self stopping. The majority of slips are halted by end resistance, in other words by the change in orientation at the grain boundaries and by the amorphous metal present at the grain boundary. If these assumptions are true, three factors may enter in the stoppage of slip: 1. the resistance of the slip plane itself; 2. the formation of amorphous metal in the slip plane, and 3. the interference of adjoining grains of different orientation.

Slip Interference

Since a ductile metal deforms or ruptures under stress by slip along crystal planes of weakness, it is evident that in order to prevent or at least retard slip, it is necessary to strengthen these planes of weakness. If we introduce some constituent into the slip planes which is inherently harder and more resistant than the ductile metal, we can retard or wholly prevent slip. The hard particles introduced into the metal will act as keys in the slip planes. For any slip plane so keyed a higher stress will be necessary to produce slip.

We know that pure alpha iron is relatively soft and weak. Now if carbon is added to iron the resulting material becomes harder and stronger. The carbon in the alloy is in the form of iron carbide, Fe_3C, a chemical compound which is inherently hard. The hard particles of Fe_3C introduced into the softer alpha iron serve as keys in the slip planes and retard easy slip along these planes. Adding copper to pure aluminum produces a like result. The copper forms the hard chemical compound $CuAl_2$ which increases the strength and hardness of the weak and soft aluminum.

The size of the hard particles is an extremely important factor in retarding or preventing slip. This is clearly evident from an examination of Figs. 42, 43 and 44 after Jeffries. In the crystal represented by Fig. 42, there are no hard particles present. Each plane is a plane of weakness where slip can occur. In Fig. 43 there is one large particle present. As the result about half of the slip planes are keyed, but the other half are not. In Fig. 44 there are many small hard particles present. The volume of the hard constituent is about the same as in Fig. 43, but it is so distributed that every plane is keyed; there can be no planes of weakness where easy slip will occur.

The slip interference theory as advanced by Jeffries and Archer is founded on this assumption namely: the cause of hardness is interference to slip. The factor that is responsible for interfering with the slip may be; 1. the resistance of the slip plane itself; 2. it may be the formation of amorphous metal in the slip plane; 3. it may be due to small grains with frequently changing orientation at the grain boundaries and with a larger volume of amorphous metal at the grain boundaries; or 4. it may be hard particles that act as keys thus preventing easy slip on the planes of weakness. The result of any of these factors is increased strength and hardness.

The slip interference theory has been widely discussed, especially in its application to the hardening of steel and the hardening of aluminum alloys. We will look at the application of the slip interference theory and compare it with other theories for the hardening of steel, in subsequent installments.

Comment and Discussion

Papers and Articles Presented Before the Society and Published in Transactions Are Open to Comment and Discussion in This Column

DISCUSSION OF THE PAPER BY DR. C. R. WOHRMAN ON "INCLUSIONS IN IRON"[1]

BY WILLIAM CAMPBELL AND G. F. COMSTOCK

DR. WOHRMAN'S excellent paper on inclusions is certainly the most valuable contribution on this subject that the writers have seen. It should be welcomed by all metallographists, and the society is to be congratulated on having such papers appear in its TRANSACTIONS. The writers especially welcome this work, which carries forward and improves upon the brief study and scheme of identification presented by us several years ago. That scheme was proposed largely as tentative, although it was the best that we could work out at the time. We are pleased to note that Dr. Wohrman has progressed further along this line and now offers a better scheme. The latter has been checked rather briefly in one of our laboratories, and it seems reliable and worthy of practical use.

The writers would like to protest against the author's statement on page 118 that Campbell and Comstock drew in their "Method of Identification" a "rigid line of demarcation between iron silicate and manganese silicate inclusions." For the sake of brevity the scheme was drawn up so that, taken by itself, it might give this impression, but if the author had taken the trouble to look up the original publication of this scheme in the *Proceedings* of the American Society for Testing Materials, and to read the introductory paragraphs there printed, he would have found that it was thoroughly understood at that time that the inclusions mentioned were not to be considered pure chemical compounds, but always more or less impure mixtures of only the approximate composition stated. Merely because the table from our paper has been copied and printed without the introductory explanation should not justify the author in condemning it for the lack of such qualifying remarks. Doubtless the arrangement and nomenclature in Dr. Wohrman's scheme, however, are better, and he has done well to emphasize the limitations of the method.

The author does not seem to have any definite proof that spots such as are illustrated in his Figs. 6 and 8 on page 95 are cavities rather than inclusions, and seems to base his conclusion on his opinion that the possibility of a transparent glass occurring as inclusions is remote. This opinion is entirely different from the writers'. Dr. C. H. Herty, Jr., of the Bureau of Mines, has found inclusions having the same appearance as the author's Fig. 6, and others have also noticed transparent inclusions which show a reflection

[1]Dr. C. R. Wohrman, "Inclusions in Iron," TRANSACTIONS, American Society for Steel Treating, Vol. XIV, July, August, September, October, 1928, pages 81, 255, 385 and 539.

of the curved under surface of the slag-metal boundary when examined in the microscope. On the other hand, cavities or pits in specimens practically never show such sharp outlines in a polished section as the round spots on Fig. 6. The author's change-of-focus test for pitting does not seem to be very reliable, in view of the undoubted occurrence of transparent, or at least translucent, inclusions in steel.

In etching the inclusions illustrated in Fig. 33 as described on page 118, the author ascribes results to the "Campbell and Comstock" method which were perhaps not warranted, as he used only a 10 per cent solution of potassium hydroxide. Such a solution would probably have no more effect on any inclusions than the well-known alkaline sodium picrate solution after the latter had been used a number of times. Both solutions may then have the effect of a moderately strong alkali. According to our scheme, "strong boiling KOH" was recommended for etching manganese silicate, and in our laboratory we use a 30 or 40 per cent solution. The author then is hardly justified in stating that "according to Comstock" no manganese silicates were present in the inclusions unchanged by 10 per cent KOH, which would not seem to be a very strong solution. Manganese silicate, in fact, has been one of the types of inclusions most commonly identified in the writers' laboratories by the "Campbell and Comstock" method, using the really strong KOH as noted above, though it was not implied that such inclusions were free from iron. However, this point in our scheme was not very definite, and the author undoubtedly has done well to omit the KOH solution from his revised scheme, retaining the alkaline sodium picrate. The writers are quite in agreement with the author in his contention that manganese oxide inclusions very rarely, if ever, occur in commercial steel.

The author's illustrations of the oxide-sulphide eutectic are remarkably fine. Such a eutectic of FeS and FeO is very commonly seen in Armco ingot iron, where it occurs in contact with the oxide globules, as was illustrated by one of the writers in the reference No. 49 mentioned on page 126.

Some of the author's statements in Chapter V seem rather dogmatic and open to criticism, but probably it is not worth while to call attention to these points in detail. The author seems to have ignored the work of Prof. E. G. Mahin (TRANSACTIONS, American Society for Steel Treating, Vol. 12, page 905, etc.), which indicated that inclusions are somewhat soluble in solid steel, and omission of consideration of the important data obtained in Prof. Mahin's work is an unfortunate exception to the author's otherwise complete review of previous literature.

In conclusion, we would again express our appreciation of the value of Dr. Wohrman's paper, and our gratification that the development of a method for identifying inclusions which we attempted to start in a tentative way several years ago, has now taken a decided step in advance.

Author's Reply to the Discussion by Campbell and Comstock

I am grateful for the able discussion offered by Messrs. Campbell and Comstock and note with satisfaction that the new scheme for identification of inclusions has been checked and indorsed by such authorities.

Messrs. Campbell and Comstock's observation in regard to the occurrence of transparent inclusions is undoubtedly correct. The author has had occasion to convince himself that the possibility of the occurrence of transparent inclusions is by far not as remote as he thought at first; in fact, silica and silicate inclusions are frequently semi-transparent or translucent and can be recognized by this feature. (The writer has taken steps to correct the paper on this point.) The spots in Fig. 6 are, however, holes; they were intentionally produced by polishing on a strongly vibrating wheel of a specimen which, when polished carefully, showed inclusions of ordinary appearance. But it must be admitted, in full accord with Messrs. Campbell and Comstock's opinion, that cavities do not exhibit ordinarily such sharp outlines as the spots of Fig. 6. It is only when an inclusion drops out in the very last stages of polishing that the original sharpness of outline is preserved. In the ordinary case, it will perhaps be safe to take sharp outlined spots to represent inclusions (silicates usually). The change of focus test for pitting remains, nevertheless, very useful. It permits to differentiate between opaque inclusions on the one hand, and cavities and transparent inclusions on the other. Examination of the outlines of individual inclusions will permit further (rough) differentiation between cavities and transparent inclusions.

The writer was well acquainted with the excellent original papers of Campbell and Comstock. It was deemed advisable, however, to discuss the "method" in the form in which it appeared in the Data Sheets of the A. S. S. T. and elsewhere, inasmuch as it was being applied in practice in this form.

Messrs. Campbell and Comstock are justified in questioning the right of the author to use a 10 per cent potassium hydroxide solution and blame the failure on their method specifying a strong solution,—as space considerations prevented the writer from publishing the complete story. Strong solutions ranging from 25 to 50 per cent potassium hydroxide were in fact used by the author in earlier determinations,—notably in his work on the identification of inclusions in Armco ingot iron. It was found that such strong solutions blackened and destroyed practically all inclusions—at any rate, all inclusions in ingot iron that had survived the attack of reagents applied earlier in the "method." As a result, some 55 per cent of the inclusions in ingot iron came under the classification of manganese-silicate, which was absurd. The author, at the time, blamed this result on his lack of knowledge of what a "strong" solution of potassium hydroxide was, and kept on diminishing the concentration of the reagent until it ceased to attack iron oxide. This led him to take the 10 per cent solution as the one meant by Campbell and Comstock.

It is unfortunate that the writer overlooked the interesting paper by E. G. Mahin and H. J. Dillon. This paper would not have appreciably influenced, however, the conclusions formulated in the present paper.

In conclusion, the writer should like to point out a new very valuable contribution to our knowledge of inclusions which recently has become available. It is a paper by C. Benedicks and H. Löfquist, ("Present Knowledge Regarding Slag (Solid Non-Metallic) Inclusions in Iron and Steel," published in La Haye, "Congrés International Pour L'Essai des Materiaux," Vol. I, 1928, pp. 265-290), which impresses by its very complete list of references, diagrams and equilibrium relationships.

Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,683,086, September 4, 1928, Cast Iron and the Method of Making Same, Augustus F. Meehan, of Chattanooga, Tennessee,

1,683,087, September 4, 1928, Cast Iron and Method of Making Same, Augustus F. Meehan, of Chattanooga, Tennessee, Assignor to Meehanite Metal Corporation, of Chattanooga, Tennessee, a corporation of Tennessee.

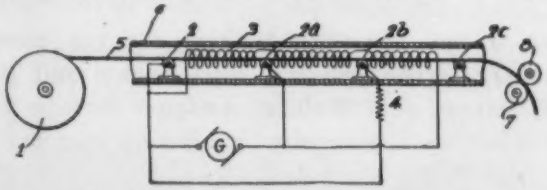
These patents describe a method of producing cast iron and of regulating the amount of carbon in graphitic form by the addition of metallic calcium, or calcium or magnesium silicide, to the iron instead of the use of ferrosilicon or the like, and in some instances also the use of a second alkaline earth metal, such as magnesium, strontium, etc., along with the silicide. The agents are usually added in the spout as the metal runs from the furnace or thrown into the stream of metal as it enters the ladle.

1,685,877, October 2, 1928, Heat Treatment of Permanent Magnets, James Edwin Gee and Frederick Samuel Gee, of London, England.

This patent describes a method of producing permanent magnets from steel containing 9 to 15 per cent of cobalt and 9 to 15 per cent of chromium, which comprises casting the steel, heating the castings to approximately 1200 degrees Fahr. to soften the same, maintaining this temperature for a half hour and then cooling and hardening by heating to approximately 2200 degrees Fahr. cooling, leaving for about 18 hours, reheating to approximately 1400 degrees Fahr. for ten minutes, allowing to cool and leaving for about 12 hours before magnetizing.

1,683, 209, September 4, 1928, Method for Increasing the Conductivity of Metals, Samuel Ruben, of New York City.

This patent describes the process of increasing the conductivity of metals by effecting a crystalline rearrangement tending to produce large crystals with the long axes of the crystals lying in the direction of the

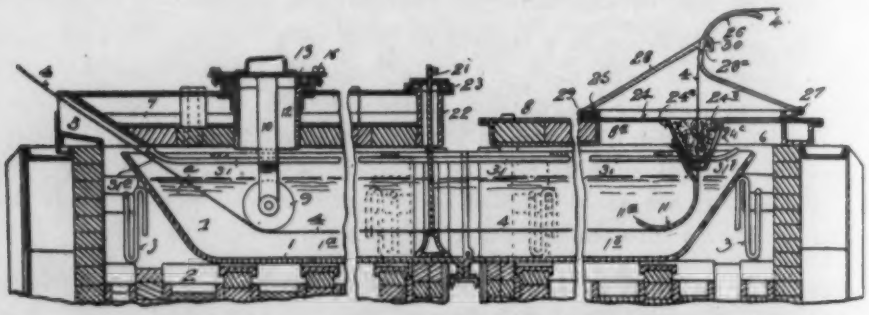


passage of current through the metal. In the embodiment illustrated, a copper wire 5 is passed through a furnace 6, containing hydrogen gas and through an electromagnetic field established from the generator G through the coils 3. The same source of energy is also used to heat the wire 5 through the roller contacts 2, 2a and 2b to a degree of temperature which

will permit the crystalline rearrangement under the influence of the heating current and the electromagnetic field.

1, 683,129, September 4, 1928, Metal-Tempering Apparatus, Henry J. Gaisman, of New York, and Conrad Schumacher, of Lynbrook, New York, Assignors to Autostrop Patents Corporation, of Dover, Delaware, a corporation of Delaware.

This patent describes a metal-tempering apparatus, particularly adapted for the heat treatment of metal in a continuous strip. The apparatus comprises a heating pot 1 divided into sections 1a and 1b which are adapted to contain a lead bath or other heating medium and to be heated to different temperatures by the resistance elements 3 spaced along the walls of the



furnace 2. The strip 4 enters through the opening 5 and is held in position in the bath by the roller 9 adjustably located therein. The strip passes out of the furnace through the opening 24 which is provided with a wiping material 24c of asbestos wool or the like, and in order to permit the strip 4 to be inserted into the furnace without losing heat therefrom by the removal of the cover 7-8, a guide strip 31 is located along the wall of the furnace permitting the threading of the strip 4 therethrough and subsequent location of the strip below the roller 9 and the slide 11.

1,683,630, September 11, 1928, Method of Making Smooth Castings, Samuel T. G. Smith, of St. Louis, Missouri.

This patent describes and claims the use of a powdered barytes ($BaSO_4$) as a facing for the walls of sand molds, cores and the like, to facilitate the production of smooth castings. The powdered barytes is said to be much superior to the usual mold facings used for this purpose.

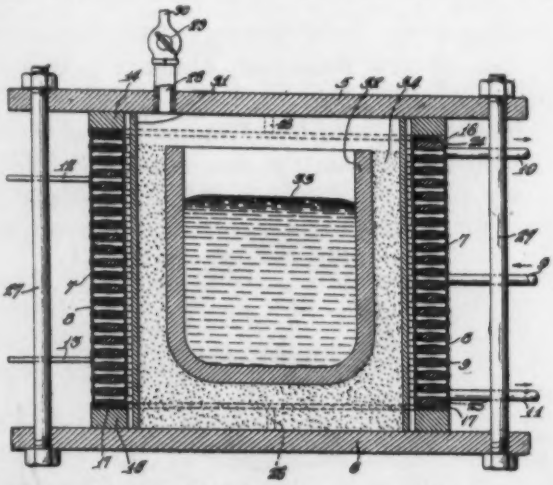
1,683,714, September 11, 1928, Process for the Production of Iron Castings with a Low-Carbon Content, Karl Emmel and Hans Walbert, of Mulheim-Ruhr, Germany; said Walbert Assignor to said Emmel.

This patent describes a method of producing iron castings with a low carbon content free from blowholes, pipes, etc. The process comprises melting in a cupola, by the use of solid fuel, a charge consisting of 50 per cent of low carbon iron, such as wrought iron or steel, the remainder of the charge consisting of pig iron of high total carbon and silicon content and the use of 9 to 13 per cent of coke. The charge is submitted to a blast pressure between 400 and 800 millimeters water gage pressure, the pressure

being varied according to whether the total carbon content in the final metal is to be nearer 2 or 3 per cent.

1,683, 986, September 11, 1928, Induction Pressure or Vacuum Furnace, Edwin F. Northrup, of Near Princeton, New Jersey, Assignor to Ajax Electrothermic Corporation, of Trenton, New Jersey, a corporation of New Jersey.

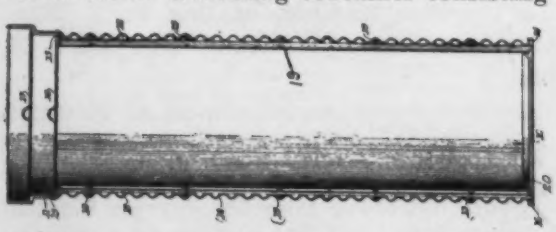
This patent describes an induction furnace of the pressure-vacuum type in which the furnace coil is used as the wall of the furnace. The coil preferably consists of a helix 8 of flattened tubing with a sealing material



7 between the coils making a fluid tight casing. The top and bottom of the furnace is sealed by the plates 5 and 6. The coil is separated from the remainder of the furnace by insulating washers 16-17 and sealing rings 14-15. The hollow coils 8 are cooled by water passing in through the pipe 9 and out through the pipes 10 and 11 and an alternating current of a frequency of 300 or 400 or more is conducted to the coil by the conductors 12 and 13. The valve 29 provides for a pressure or vacuum attachment to the furnace and the crucible 32 is surrounded by zirconium sand or the like 34 which insulates the crucible.

1, 684,391, September 18, 1928, Container for Annealing and Similar Purposes, J. Birchard Green, of Chicago.

This patent describes an annealing container consisting of end walls 10

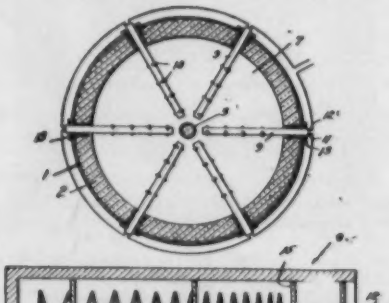


and 11 connected together by rods 12 forming a skeleton framework adapted to withstand the repeated heating and cooling of an annealing box. The side walls of the container are preferably closed by corrugated sheet metal

14, the corrugations extending parallel to the direction of greatest expansion and contraction, and the inside of the container may be provided with a sheet metal liner 19 and provided with a double sealed closure 17 and 18. Annular hoops 13 surround the rods 12 at spaced intervals. The use of the strong skeleton framework, formed by the rods 12 and hoops 13, provides a box of sufficient strength to withstand annealing and sufficiently free to expand and contract under the influence of repeated heating and cooling to prevent destruction thereof, while the corrugated sheet metal outer wall 14 and the sheet metal inner liner 19 readily conform to any distortion of the framework without rupture.

1,685,226, September 25, 1928, Heating High-Temperature Apparatus, Charles Lalor Burdick, of New York City, Assignor to Guggenheim Brothers, of New York City, a copartnership.

This patent describes an electrical metallurgical furnace of a shaft type in which the resistance heating elements, consisting of coils 16, are located in refractory tubes 9 projecting radially through the walls of the



shaft 1 and supported therein by suitable hooks 10 in such a manner as to permit the removal of either the refractory tubes themselves, for the purpose of replacing the same, or the removal of the resistance coil from the inside of the tube in case either the tube or the coil becomes defective. In order to compensate for the greater area to be heated along the wall of the shaft the coils 16 are spaced to generate progressively more heat from the center to the outside of the furnace.

1,677,139, July 17, 1928, Process for Increasing the Permeability of Silicon Steel, John Clarence Karcher, of Oak Park, Illinois, Assignor to Western Electric Company, Incorporated, of New York, N. Y., a corporation of New York.

This patent describes a commercial process of increasing the magnetic permeability of silicon steel which consists in heating the silicon steel to a temperature above 1000 degrees Cent. and below 1250 degrees Cent., cooling to a temperature not lower than 550 degrees Cent. and then cooling quickly from this temperature to a temperature sufficiently low so that controlling the rate of cooling will have substantially no effect, that is to a temperature of around 200 to 250 degrees Cent.

THE ENGINEERING INDEX

Registered United States, Great Britain and Canada

Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each week with a specially prepared section of The Engineering Index Service. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the Weekly Card Index Service of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,700 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

ALLOY STEEL

ANTI-CORROSIVE. A New French Metal Refractory to Corrosion, Chaudaye. *Institut International du Froid (Information on Refrigeration)—Bul. (Paris)*, vol. 9, no. 1, Jan.-Feb. 1928, pp. 49-51. (English Edition).

Metal with trade name of Apso developed by Pompey Steel Works, is claimed to have remarkable corrosion-resistant properties and is of moderate price; studies on influence of copper, with graduated percentage on steels; Pompey also manufactures Apso steels possessing characteristics of semi-hard steels and spring mangano-siliceous steels. Abstract translated from French.

PROPERTIES. Investigation of Influence of Silicon and Nickel in Hardened Steel on Annealing Processes (Die Anlassvorgaenge im gehaerteten Stahl und ihre Beeinflussung durch Silizium und Nickel), H. Birnbaum. *Stahl und Eisen (Duesseldorf)*, vol. 48, no. 33, Aug. 16, 1928, pp. 1125-1126, 1 fig.

Abstract of report published in Archiv fuer das Eisenhuettenwesen (Duesseldorf), July 1928, previously indexed.

ALLOY STEELS

ANALYSIS. Determination of Chromium and Vanadium in Iron Alloys and Superior Steels (Bestimmung von Chrom und Vanadin in Ferrolegierungen und Edelstaehlen), E. Zintl and P. Zaimis. *Zeit. fuer angewandte Chemie (Berlin)*, vol. 41, no. 21, May 26, 1928, pp. 543-246, 1 fig.

In determination of chromium and vanadium by authors' potentiometric method, presence of iron is not essential; small quantities of manganese must, however, be present. See brief translated abstract in Chem. and Industry (Lond.), vol. 47, no. 29, July 20, 1928, p. 525.

COPPER ADDITION. Corrosion Tests on Steel With Copper Addition (Natur-Rostungsversuche mit gekupfertem Stahl), K. Daeves. *Stahl u. Eisen (Duesseldorf)*, vol. 48, no. 34, Aug. 23, 1928, pp. 1170-1171, 4 figs. on supp. plate.

Results of two-year comparative tests with copperized and non-copperized steel in galvanized and non-galvanized state.

MANUFACTURE. The Manufacture of Alloy Steel, E. C. Smith. *Iron and Steel of Can. (Gardenvale, Que.)*, vol. 11, no. 8, Aug. 1928, pp. 242-244.

Inquiry into alloy-practice conditions; control of charge necessary; furnaces and fuels used; many intangibles included in customer's demands; methods of adding alloys; ingot practice must be good; slow rolling in smooth rolls; alloy steels like old branded products; fine alloy steels from basic open hearth. Paper presented to Am. Iron and Steel Inst.

PROPERTIES. Physical properties of Alloy Steels Under Various Heat Treatments, etc.; C. B. Callomon. *Iron and Steel (A. S. M. E. Trans.)*, vol. 50, no. 16, May-Aug. 1928, pp. 1-3.

Description of so-called "stainless" iron, steel containing 12 to 16 per cent chromium and less than 0.12 per cent carbon; and "super" stainless iron containing 12 to 20 per cent chromium and 7 to 10 per cent nickel; former is readily machinable; second alloy, strength of which is increased by hot or cold working rather than by heat treatment, resist corrosion much better, but is more difficult to form and machine; both have high tensile strength at elevated temperatures.

CASE HARDENING

Factors in Case Hardening. *Can. Machy.*

Those members who are making a practice of clipping items for filing in their own filing system may obtain extra copies of the Engineering Index pages gratis by addressing their request to the society headquarters, whereby their names will be placed on a mailing list to receive extra copies regularly.

(Toronto), vol. 39, no. 16, Aug. 9, 1928, pp. 43-44.

For satisfactory results with plain carbon steels, carbon content must be low enough to ensure that high temperatures employed in carburizing do not result in embrittling core; selecting carburizing compounds; temperatures for carburizing. Abstract from Black and White, compiled by research staff of E. F. Houghton & Co.

NITRATION. Steels for Case Nitrification, A. B. Kinzel. *Can. Machy. (Toronto)*, vol. 39, no. 17, Aug. 23, 1928, pp. 56 and 89.

Reprint of paper presented before Am. Soc. Steel Treating, previously indexed.

NITRATION. A Note on The Expansion Due to Nitration of A Special Alloy Steel, R. H. Hobrock. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 3, Sept. 1928, pp. 337-342, 5 figs.

There is expansion occasioned by nitration process alone that may not be eliminated by annealing operation; amount of this expansion is function of time of treatment and of thickness of case produced; data have been gathered and correlated for one such form as to make calculation of amount of expansion quite simple.

CAST IRON

ANALYSIS. Notes on the Routine Analysis of Cast Irons and Iron Foundry Raw Materials, A. Smith. *Foundry Trade Jl. (Lond.)*, vol. 39, nos. 627 and 628, Aug. 23 and 30, 1928, pp. 137 and 145 and 152, 1 fig.

Aug. 23: Estimation of silicon; procedure for routine method; ferromanganese or spiegeleisen; ferronickels and silicon-nickel alloys. Aug. 30: Estimation of sulphur.

GRAPHITIZATION. Graphite in Grey Cast Iron and Its Influence Upon the Mechanical Properties, P. Bardenheuer and K. L. Zeyen. *Foundry Trade Jl. (Lond.)*, vol. 39, no. 627, Aug. 23, 1928, pp. 133-136, 6 figs.

Authors, after carefully studying all experiments hitherto made, came to conclusion that some questions arising from this problem are not yet fully answered; they, therefore, carried on the following experiments: solubility of graphite; influence of superheating; graphite controlling factor; treating molten iron. Abstract translated from Giesserei (Duesseldorf), nos. 16, 17 and 18, 1928, previously indexed.

PEARLITIC. High-Grade Cast Iron (Hochwertiges Gusseisen), H. Jungbluth. *Maschinenbau (Berlin)*, vol. 7, no. 16, Aug. 16, 1928, pp. 766-770, 3 figs.

Compilation based on recent papers in German and in English, by Piwowarsky, Kerpely, Young, and others; improvement of cast iron by addition of other metals, production of pearlitic mass, reduction in graphite content, etc.

TESTING. Transverse Tests on Round and Square Bars of Grey Cast Iron, A. L. Norbury. *Brit. Cast Iron Research Assn.—Bul. (Birmingham)*, no. 21, July 1928, pp. 25-27, 4 figs.

It is well known that square transverse test bars of cast iron give lower modulus of rupture value than round bars of approximately same cross-section; tests show that large part of difference is due to fact that modulus of rupture formulas generally used do not hold in case of cast iron when applied to compare transverse test results on round bars with those on square bars.

CUPOLAS

CHARGING. A New System of Cupola Charging. *West. Machy. World*, vol. 19, no. 8, Aug. 1928, pp. 365-367, 5 figs.

New system, called Whiting Wishbone system, based on use of special dump buckets for holding coke and iron is described; original method of dumping bucket; system applicable to crane or monorail chargers; bucket more adaptable to small cupolas than cone bottom.

ELECTRIC FURNACES

BASIC—REACTIONS. Reactions in the Basic Electric Furnace, K. von Kerpely. *Fuels and Furnaces*, vol. 6, no. 8, Aug. 1928, pp. 1091-1092.

Discussion of various reactions taking place; methods of fusion, deoxidation, deoxidizers, kinds of slags.

HEAT TREATING. Gyratory Electric Furnace for Hardening Small Parts (Horno electrico giratorio para endurecer piezas pequenyas). *Ingenieria Internacional*, vol. 16, no. 8, Aug. 1928, p. 392, 1 fig.

Brief description.

HEAT TREATING. Carbonizing Dodge Parts Electrically. *Iron Age*, vol. 122, no. 9, Aug. 30, 1928, pp. 513-515, 3 figs.

At Detroit plant manufacturing Dodge motor cars; carburizing is done in special types of furnaces, heated with electric resistors; parts quenched from pot given 10½ to 16½ hr. heat in turret furnace; pot-cooled parts stay twice as long in straight-line counterflow furnace.

HIGH FREQUENCY. The High-Frequency Furnace with Rotating Spark Gap and Variable Oscillating Coefficient (Ein Hochfrequenzofen mit rotierender Funkenstrecke und veraenderlicher Schwingungszahl), M. H. Kraemer. *Stahl und Eisen (Duesseldorf)*, vol. 48, no. 33, Aug. 16, 1928, pp. 1120-1124, 6 figs.

Description of a furnace built in Metallurgical Institute of Berlin Institute of Technology, of 25 kw. maximum output with damped oscillating circuit, and oscillating coefficient varying between 230,000 and 14,000 Hertz; furnace has high melting speed, is simple in design, and initial and maintenance costs are low.

IRON FOUNDING. Making Cast Iron in the Electric Furnace. *Fuels and Furnaces*, vol. 6, no. 8, Aug. 1928, pp. 1077-1078.

Comprehensive investigation of making of cast iron has been completed by U. S. Bureau of Mines at its Northwest Experiment Station, Seattle, Wash.; cast-iron scrap of high-sulphur content can be converted into high-grade cast iron, low in sulphur, either by melting directly in electric furnace or by refining molten metal from cupola.

REFRACTORY MATERIALS. Refractory Materials for Electrical Metallurgical Furnaces, A. B. Searle. *Iron and Steel Industry (Lond.)*, vol. 1, no. 11, Aug. 1928, pp. 343-345.

Use of monolithic or tamped hearths; walls for electric furnaces; roofs usually made of silica bricks and this is chief cause of trou-

ble; air or water cooling of ring around electrode; on no account should insulating bricks be used in roof; cement or mortar used for building electric furnace; precautions in selecting refractory materials.

STEEL MAKING. Electric Furnaces, Brown-Boveri System with Hydraulic Regulation of Electrodes (Fours électriques système Brown-Boveri à reglage électro-hydraulique des électrodes), E. de Mulinen. *Génie Civil (Paris)*, vol. 93, no. 6, Aug. 11, 1928, pp. 143-145, 5 figs.

Describes electric furnace of 20 tons capacity installed at Aosta; has 3 electrodes of 600 mm. diam. for 15,000-amp. current; how electrodes are regulated.

FORGINGS

The Behaviour of Metals and Alloys During Hot-Forging, W. L. Kent. *Mech. World (Lond.)*, vol. 84, no. 2173, Aug. 24, 1928, pp. 181-182.

Paper read before Inst. of Metals previously indexed from advance paper.

BRASS—HEAT TREATMENT. The Heat Treatment of Drop Forged Brass, R. Hinzmann. *Fuels and Furnaces*, vol. 6, no. 8, Aug. 1928, pp. 1047-1050, and 1069-1070, 16 figs.

Investigation refers to brass alloy containing 50 per cent copper, 2 per cent lead, and balance zinc; quality and mechanical properties of finished product depend very much on heat treatment to which alloy has been subjected under extrusion and before drop forging. Translated from Zeit. fuer Metallkunde.

HEAT TREATMENT. Determination of the Heating Time for Forgings. *Fuels and Furnaces*, vol. 6, no. 8, Aug. 1928, pp. 1081-1082, 2 figs.

Heating time of forging can be determined as function of its surface and its volume; in order to make practical use of equation, graphic chart called furnace chart, developed by H. Freund, makes it possible to determine rapidly heating time for forgings. Abstract translated from Maschinenbau.

STEEL—HEAT TREATMENT. The Need for Better Forge Heating, D. K. Bullens. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 875-880, and 888, 27 figs.

Difficulty encountered in heat-treating operations largely due to improper forging methods; description of design and operation of furnaces; trend of practice should be toward lower furnace temperatures; loading should be reasonable with regard to method of exposing each individual piece to heat in similar manner; lower rate or heating to permit of thorough saturation; better application of heat to metal and better utilization of heat within furnace; control of air entering furnaces.

STEEL—HEAT TREATMENT. Heat Treating Ball Races by Machinery, L. A. Lanning. *Am. Mach.*, vol. 69, no. 8, Aug. 23, 1928, pp. 229-302, 6 figs.

Seventy-five tons of ball-race forgings are handled daily through heat-treatment department of New Departure Mfg. Co., incidental to manufacture; most of it by automatic materials-handling equipment; description of processes, furnaces and materials-handling methods is given.

FURNACES

ANNEALING—NORMALIZING. Furnaces and Methods in Normalizing. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 915 and 917.

Process in normalizing is to increase heat slowly and uniformily until desired temperature is attained; after "soaking" piece sufficiently, it is allowed to cool freely in air; uniformity of temperature is imperative; annealing furnaces may be used for normalizing except in treatment of sheet steel where continuous furnace is generally used; special alloys necessary for furnace parts in order to withstand temperature; gas more satisfactory than oil as fuel since it can be regulated more precisely.

ENAMELING. Continuous Enameling Furnace, O. W. Owen. *Am. Ceramic Soc.—Jl.*, vol. 11, no. 9, Sept. 1928 (Bul. Sec.), pp. 272-276, 2 figs.

Details are given of moving of ware through new continuous outerflow furnace for fusing enamel; among advantages of this new type are smaller loss of ware and saving in time and money.

FORGING—GAS FIRING. Gas-Fired Forges at McCormick Works, J. B. Nealey. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 908-909, 3 figs.

Description of new furnaces and burners at McCormick plant of International Harvester Co.; individual furnaces are mounted on standards constructed of pipe with cross-members for stiffening legs; there is clearance of 12 in. between floor and cross-members so that furnaces may be handled with standard elevating trucks; regulation of flame and precautions against overheating.

FORGING—PULVERIZED COAL. Forge Furnaces Burn Powered Coal, C. Rehfuss. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 910-914, 8 figs.

Abstract of paper presented before Am. Soc. Mech. Engrs., previously indexed.

HEAT TREATING. Furnaces for Various Heat Treatments, P. C. Osterman and E. C. Cook. *Heat Treating and Forging*, vol. 14, nos. 7 and 8, July and Aug. 1928, pp. 781-784 and 903-907, 14 figs.

July: Oven semi-muffle furnace is described in connection with treatment of high-speed steel tools; vertical cylindrical type furnaces and salt baths adaptable for certain purposes; electric and gas-fired furnaces compared. Aug.: Case-hardening problems are reviewed and number of installations are described.

HEAT TREATING—AUTOMATIC CONTROL. Automatic Surface Control for Hardening. *Iron Age*, vol. 122, no. 10, Sept. 6, 1928, p. 579, 3 figs.

Uniformity in hardening gears has been obtained by installation of gas-fired furnace with variable-speed rotating hearth; hearth makes complete revolution in from 20 min. to 2 hr., depending upon character of work; furnace has two heating zones; temperature of 1600 deg. fahr. may be maintained with 1.2 cu. ft. of 570 B.t.u. gas for each pound of work.

HEAT TREATING, GAS-FIRED. Special Gas-Fired Furnace Built to Heat Treat Manganese Steel Castings, O. W. Andersen. *Foundry*, vol. 56, no. 16, Aug. 15, 1928, pp. 662-665, 6 figs.

Brief résumé of early history and some of modern developments pertaining to manufacture of manganese steel; applications for which wear-resisting properties make it useful; novel features of gas-fired furnace installed in plant of Pettibone Mulliken Co., Chicago, for heat treating manganese steel; combustion confined to specially designed refractory combustion chamber.

HARDNESS TESTING

Hardness Testing, H. M. German. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 3, Sept. 1928, pp. 343-354, 13 figs.

Paper presents some newer ideas pertaining to Brinell, Rockwell, and scleroscope hardness testing; charts showing comparative hardness values of Brinell with Rockwell C. Rockwell B and scleroscope; brief description of Vickers and monotron hardness testing machines.

(ROCKWELL). The Rockwell Hardness Test, J. E. Malam. *Inst of Metals—Advance Paper (Lond.)*, no. 472, for mtg., Sept. 4-7, 1928, 20 pp., 10 figs.

Work carried out to furnish data for conversion between Rockwell and Brinell and Rockwell and scleroscope numbers for copper, 95:5, 70:30, and 63:37 copper-zinc, and 80:20 cupro-nickel; conclusion is reached that Rockwell ball test in its present form yields so-called "hardness numbers" which must be considered as quantitatively misleading and unscientific results are obtained owing to arbitrary numbering of scleroscope scale; suggests that representative committee be set up in order to consider whole subject of hardness testing.

HARDNESS TESTING MACHINES

Routine Hardness Testing. *Automobile Engr. (Lond.)*, vol. 18, no. 244, Aug. 1928, pp. 304-305, 2 figs.

Description of machine previously indexed from Machy. (Lond.), July 12, 1928.

IRON AND STEEL METALLURGY

Metallurgical Theories for the Practical Iron and Steel Man, C. H. Plan. *Iron and Steel Industry (Lond.)*, vol. 1, no. 11, Aug. 1928, pp. 350-352.

Description of procedure necessary to obtain specimens suitable for observation through eye piece of microscope, method of cutting sections of metal; operations involved in polishing, fine grinding, finishing and etching; procedure and benefits derived from macrographic examination.

MANGANESE STEEL

MANUFACTURE—ELECTRIC PROCESS. Making Electric Manganese Steel, J. H. Hruska. *Iron Age, vol.* 122, no. 8, Aug. 23, 1928, pp. 455-456, 2 figs.

Homogeneous metal, practically negligible losses of manganese, few non-metallic and gaseous inclusions and possibility of hotter steel, are advantages of making manganese steel in basic electric furnace; production costs are higher, however, as compared with open-hearth process.

METALS

CORROSION. Action on Metals in Contact with Corroding Liquids, G. A. Luers. *Refrig. World*, vol. 63, no. 8, Aug. 1928, pp. 48-50.

Table given has been prepared from tests of specimens of metals in contact with liquids; materials listed, while common to everyday practice, are not generally included in textbooks.

CUTTING. Start and Finish of Cutting Work. *Times Trade and Eng. Supp. (Lond.)*, vol. 22, no. 527, Aug. 11, 1928, p. 548.

Special considerations nearly always require to be borne in mind at beginning and termination of cutting movement, including problem of shop reduction, production of accurate lead or start, and prevention of damage to tool edges on return movements.

DEFORMATION. Experimental Study on Plastic Deformation (Étude expérimentale sur les déformations plastiques), P. A. Welikhoff and N. P. Stchapoff. *Revue de Métallurgie (Paris)*, vol. 25, no. 6, June 1928, pp. 299-311, 18 figs.

Study of soft steels made in laboratory of Institute of Transports at Moscow; method used for test specimens, cylindrical in form; microscopic examinations; instruments used in measuring deformation of grain structure.

FAILURES. Engineering Component Failures: Causes and Remedies. *Mech. World (Lond.)*, vol. 84, no. 2172, Aug. 17, 1928, pp. 154-155, 2 figs.

Author investigates underlying causes of failure of metallic components, and shows that such troubles may be due to faults in design and machinery as well as to purely metallurgical faults; practical methods for detecting these faults are given, and suggestions made for their elimination.

FATIGUE. "Tired Steel" H. F. Moore. *Engrs. and Eng.*, vol. 45, no. 8, Aug. 1928, pp. 171-178, 16 figs.

Fundamental considerations in computing stresses in metal; metallographic microscope as aid in stress analysis; localized stresses; must be taken into account as well as widely distributed stresses; methods to use in testing metals for fatigue; design of specimens; effect of surface finish; utilization of results of tests. Abstract of address presented before Am. Soc. Steel Treating.

FATIGUE. What is Fatigue (Was ist Ermuedung?), K. Laute and G. Sachs. *V. D. I. Zeit. (Berlin)*, vol. 72, no. 34, Aug. 25, 1928, pp. 1188-1189, 2 figs.

Report from government testing laboratory and Kaiser Wilhelm Institute for metal research at Berlin-Dahlem; review of fatigue of metals studies by Gough, Ludwik, Moore and Kommers, and others; new experiments by authors showing weakening effect of heat treatment on nickel bars subjected to vibrations repeated millions of times.

HEAT CONDUCTIVITY. Heat Conductivity of Metals as Factor in Heat Transfer, R. Worthington. *Chem. and Met. Eng.*, vol. 35, no. 8, Aug. 1928, pp. 481-482.

Phases, heat transfer and heat conductivity, are applied to two distinct physical characteristics of flow of heat; although heat conductivity of metals is seldom consideration in choice of materials of construction from heat-exchange apparatus, it is necessary to appreciate that metals differ in efficiency with which they transmit heat according to their susceptibility to chemical attack and to physical characteristics of products of attack; examples of effect of surface conditions of metal on heat-transfer rates.

IMPURITIES. Impurities in Metals, C. J. Smithells. *Times Trade and Eng. Supp. (Lond.)*, vol. 22, no. 529, Aug. 25, 1928, p. 596.

Review of book published by Chapman and Hall; purpose of work is to give account of influence of impurities in metals on their structure and properties.

TESTING. Metals Studies for Fifteen Years, H. W. Gillett. *Iron Age*, vol. 122, no. 9, Aug. 30, 1928, pp. 509-512, 5 figs.

Review of achievements since organization of metallurgical division of Bur. of Standards in 1913; much effort put on developing correct methods of test.

TESTING. The Fracture of Notched Tensile Test Pieces (Der Bruch gekerbter Zugproben), W. Kuntze. *Archiv. fuer das Eisenhuettenwesen (Duesseldorf)*, vol. 2, no. 2, Aug. 1928, pp. 109-117, 11 figs.

Influence of shape and depth of notched on fracture in tensile test piece; definition of fracture resistance, its determination and its relation to stretching, drawing, and heat treatment; fatigue due to deformation.

WEAR TESTING. The Wear of Metals and Its Determination. *Engineering (Lond.)*, vol. 126, no. 3267, Aug. 24, 1928, p. 237.

Fact emerges that, just as it is difficult to reproduce in laboratory actual conditions which bring about corrosion, so is it difficult to reproduce artificially conditions which occasion wear; resistance to wear, owing partly to complex nature of physical characteristics involved and partly to wide range or service conditions which have bearing on question, must be determined, in many cases, by more or less tedious long-time full-scale tests.

X-RAY ANALYSIS. Chemical Analysis by X-Rays, A. H. Turner. *Chem. Eng. and Min. Rev. (Melbourne)*, vol. 20, no. 238, July 5, 1928, pp. 361-363.

Discusses X-Ray analysis in general; data on tests made on metals and alloys; results show that considerable accuracy would be obtained; permit detection of impurities of order of one part in million.

X-RAY ANALYSIS. Spectrographs of Alloys by X-Ray (La spectrographie des alliages par les rayons X), H. Weiss. *Société Chimique de France—Bul. (Paris)*, vol. 43-44, no. 7, July 1928, pp. 697-711, 13 figs. partly on supp. plate.

Study of structure of metals and alloys; influence of size of crystals; orientation of crystals and of electrolytic deposits. Bibliography.

METALLOGRAPHY

Metallography Simplified for Practical Use In Shop, E. Preuss, G. Berndt, M. v. Schwarz. *Iron Trade Rev.*, vol. 83, no. 8, Aug. 23, 1928, pp. 444-445.

It has been shown previously that segregated zones of steel and different layers of wrought iron change with rolling or forging at higher temperatures; same condition holds to much greater extent for all changes in shape in cold condition, as with upsetting, cutting, riveting, stamping, etc.; it is important to determine, especially with boiler plates, whether rivet holes are drilled or punched; of especial interest with soft steel are "aging appearances" which occur after cold working.

MICROSCOPES

New Microscopes. *Jl. of Sci. Instruments*, vol. 5, no. 7, July 1928, pp. 225-227, 4 figs.

Description of instruments of new design with substage apparatus which can be rapidly changed from transparent to dark background without affecting adjustment.

NICKEL STEEL

UTILIZATION. Recent Developments in the Use of Nickel Steels, C. McKnight. *Iron and Steel (A.S.M.E. Trans.)*, vol. 50, no. 16, May-Aug. 1928, pp. 9-14, 4 figs.

Author discusses early uses of nickel steel for plate, guns, and projectiles; development of its use in locomotive construction for heavy forgings and for shell plates of high-pressure locomotive boilers; touches briefly on three recently developed iron-nickel alloys: invar, permalloy, and nickeloy, and with substitution of nickel-chrome-steel castings, for those of manganese steel in trackwork; advantageous properties conferred on cast iron by addition of nickel.

OPEN-HEARTH FURNACES

DESIGN. Improvements in Open Hearth Furnaces with Moll-Type Head (Neuerugen an Siemens-Martin-Oefen mit Moll-Kopf), K. H. Moll. *Stahl u. Eisen (Duesseldorf)*, vol. 48, no. 34, Aug. 23, 1928, pp. 1160-1165, 6 figs.

Report No. 146 of Steel Works Committee of Verein deutscher Eisenhuettenleute. Combustion process in hearth; arrangement of burner; description of air chamber with ante-chamber; checker arrangement of Moll-Rhenania brick; operating results; details of new valve.

PYROMETRY

Note on Practical Pyrometry, G. B. Brook and H. J. Simcox. *Inst. of Metals—Advance Paper (Lond.)*, no. 470, for mtg., Sept. 4-7, 1928, 10 pp., 12 figs.

Paper outlines difficulties, such as stray current and magnetic fields of great intensity, which are peculiar to industries where large currents are used; instrument has been designed which eliminates these and is accurate even when placed in field surrounding conductor carrying as much as 20,000 amperes; description of quick-reading thermocouple which is suitable for use in nonferrous foundries.

STAINLESS STEEL

Stainless-Steel Girdle Round the Dome of St. Paul's Cathedral. *Iron and Coal Trades Rev. (Lond.)*, vol. 117, no. 3153, Aug. 3, 1928, p. 165, 1 fig.

Illustration and brief text describing strengthening girdle constructed of Brown Bayley "two-score" stainless steel; designed like bicycle chain, with standardized links and pins; ultimate tensile strength 45 to 50 tons per sq. in.; total length about 450 ft.

WELDING. The Welding of Stainless Irons and Steels. *Welding Jl. (Lond.)*, vol. 25, no. 298, July 1928, pp. 208-210, 4 figs.

Problem of welding stainless steels with oxyacetylene blowpipe has been thoroughly investigated by French Welding Association; results of investigations; effect of flame regulation was studied; draws special attention to method of applying flux in order to obtain

best results, because this is essential factor for success.

STEEL

AIRCRAFT. Steel in Aircraft Construction, E. A. Richardson. *Mech. World (Lond.)*, vol. 84, no. 2171, Aug. 10, 1928, pp. 135-136.

Paper presented before Am. Inst. Min. and Met. Engrs., previously indexed from their Tech. Pub. No. 94.

AIRCRAFT. Steel in Aircraft Construction, E. A. Richardson. *Mech. World (Lond.)*, vol. 84, no. 2173, Aug. 24, 1928, p. 184.

Paper presented before Am. Inst. of Min. & Met. Engrs. Previously indexed from its technical bulletin.

ANALYSIS—VANADIUM DETERMINATION. The Determination of Vanadium in Steel, A. T. Etheridge. *Analyst (Cambridge, England)*, vol. 53, no. 629, Aug. 1928, pp. 423-428.

Description of method which has proved to be accurate for all kinds of steels, consisting in removing iron and other interfering metals, leaving solution of vanadium which can be determined by ordinary permanganate titration; operations are removal of iron as chloride by either extraction process, followed by removal of rest of interfering metals by electrolysis over mercury cathode.

AUTOMOBILE. British and American Automotive Steels, J. W. Urquhart. *Heat Treating and Forging*, vol. 14, nos. 7 and 8, July and Aug. 1928, pp. 751-753 and 852-855 and 862.

July: Comparison of heat-treating methods are given and reasons for use of super-steels reviewed; air hardening nickel-chrome series coming into use; heavy and light engines; Aug.: Carburized plain and nickel-steel die block.

CARBURIZING. A Note on the Effect of Heat Treatment on Abnormal Case Carburizing Steels, B. M. Larsen and A. W. Sikes. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 3, Sept. 1928, pp. 355-362, 10 figs.

Case-carburizing steels may exhibit either grain-size abnormality or structural abnormality; abnormal grain structures may be changed or modified by various heat treatments in same way as in other steels; structural abnormality, which involves tendency toward separation of ferrite and cementite in hypereutectoid zone of case, is not appreciably affected by heat treatment even at temperatures around 2000 to 2050 degrees Fahr.; photomicrographs are presented.

COLD DRAWING. Study of Cold Drawing of Soft Steel (Contribution à l'étude de l'étirage à froid de l'acier doux), R. Giraud. *Revue de Métallurgie (Paris)*, vol. 25, no. 6, June 1928, pp. 347-354, 4 figs.

Measure of work absorbed by metal under form of potential energy; method of testing and table of tests with results of cold drawing.

DEVELOPMENTS. Engineering Developments in Steel, B. D. Saklatwalla. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 863-869, 1 fig.

Paper presented before Am. Section of Soc. Chem. Industry of London, previously indexed.

HEAT TREATMENT. Facts and Principles Concerning Steel and Heat Treatment, H. B. Knowlton. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 3, Sept. 1928, pp. 415-434.

First of series of articles on heat-treating equipment and methods. Among subjects discussed are: fundamental requirements of heating equipment, pyrometers, simple box-type furnaces, coal, oil, gas, and electric heating.

HEAT TREATMENT. Heat Treatment of Ferrous Metals, C. M. Walter. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 884-888, 6 figs.

Abstract of paper presented before Soc. Chem. Industry, previously indexed, from Gas. Jl., May 2, 1928.

HEAT TREATMENT—TEMPERATURE CONTROL. Heating of Steel By the Controlled Temperature Method, G. W. Hegel. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 3, Sept. 1928, pp. 377-384, 7 figs.

Author demonstrates effect of rate of heating through critical range on temperature distribution in piece of steel; he shows how best results can be obtained by controlling maximum temperature.

HEAT TREATMENT. Rational Heating of Steels (La pratique du chauffage rationnel des aciers), P. Lavigne. *Pratique des Industries Mécaniques (Paris)*, vol. 11, no. 5, Aug. 1928, pp. 207-211, 5 figs.

Author describes method used to bring steel up to proper heating point for tempering; drawing is mentioned briefly and various kinds of mechanical working; salt baths used for heating.

HEAT TREATMENT—TERMINOLOGY. Definitions Relating to the Heat Treatment of Iron and Steel. *Fuels and Furnaces*, vol. 6, no. 8, Aug. 1928, p. 1078.

Abstract of report presented before Am. Soc. Testing Materials, previously indexed.

STRENGTH TESTING. Prolonged Stress, Structure and Mechanical Hysteresis of Steel (Dauerbeanspruchung, Gefuege and Daempfung), W. Herold. *Stahl u. Eisen (Duesseldorf)*, vol. 48, no. 31, Aug. 2, 1928, pp. 1051-1052, 4 figs.

Abstracts of paper published in Archiv Eisenhuettenwesen, July 1928, previously indexed.

STRUCTURE. The Structure of Hardened Carbon Steel (Kolstalens hardningsstruktur), B. D. Enlund. *Jernkontorets Annaler (Stockholm)*, no. 7, 1928, pp. 374-393 and (discussion) 393-394, 18 figs.

Results of recent studies of structure and nature of hardening with special reference to distribution of carbon percentage, particularly in hypoeutectoid steels.

WIRE TESTING

Further Mechanical Tests of Wire, J. D. Brunton. *Wire*, vol. 3, no. 8, Aug. 1928, pp. 258-259, and 277-280, 3 figs.

Methods and apparatus for determining ultimate stress, yield point, elastic limit, and torsional resistance; careful handling required; types of extensometers; technique of testing; torsional standards.

News of the Chapters

SCHEDULED MEETING NIGHTS OF CHAPTERS

For the convenience of visiting members, those chapters having scheduled meeting nights are listed below.

BOSTON—First Friday. H. E. Handy, secy., Saco-Lowell Shops, Lowell, Mass. Phone, Lowell 4050.

CHICAGO—Second Thursday. J. A. Comstock, secy., Peoples' Gas Light & Coke Co., Chicago.

Nov. 8—Tool Steel Performance ..... J. P. Gill
Dec. 13—Heat Resisting Alloys ..... F. A. Fahrenwald
Jan. 10—Nitriding ..... V. O. Homerberg
Feb. 14—Drop Forgings ..... R. B. Schenck
Mar. 14—Machinability of Metals ..... A. H. d'Arcambal
Apr. 11—Theoretical Metallurgy ..... Zay Jeffries
May 9—Heat Treatment of Tools ..... J. F. Keller
June 8—Annual Picnic.

DAYTON—Third Monday. Fred M. Reiter, secy., Dayton Power and Light Co., Dayton, Ohio.

Nov. 19—Nitride Hardening of Steel ..... Henry DeFries
Dec. 17—Pyrometry and Automatic Temperature Control ..... C. S. Gordon
Jan. 21—Production Heat Treating ..... H. M. Spears
Feb. 18—Gray Cast Iron ..... J. W. Bolton
Mar. 18—Open for Requested Selection.
Apr. 15—Subject to be Selected ..... P. D. Merica
May 20—Program Entirely at Wright Field ..... J. B. Johnson
June Meeting—Annual Banquet.

DETROIT—J. G. Gagnon, secy., Hudson Motor Car Co., Detroit. Phone, Lennox 3232.

Nov. 19—Gears and Gear Steels ..... E. C. Smith
Dec. 17—Social Meeting.
Jan. 21—Fatigue of Metals ..... H. F. Moore
Feb. 18—Metal Stamping ..... Geo. Kelley
Mar. 18—Relation of Metallurgist to Management ..... C. F. Kettering
Apr. 14—Classification and Applications of Tool Steels .... To be announced
May —Ann Arbor Meeting, date, subject and speaker to be announced later.

GOLDEN GATE—Third Wednesday. H. E. Morse, secy., Morse Laboratories, San Francisco.

Nov. 21—Refractories and Their Uses—a six reel movie.
Dec. 12—Welding and Welded Sections.
Jan. 16—Meeting left open in order to arrange program for National Society members from Convention.
Feb. 20—Corrosion and Corrosion Resisting Materials.
Mar. 20—Aircraft Materials.
Apr. 17—Heat-Treating Steel and Cast Iron Castings.
May 15—Structural and Railroad Steels.
June 19—Pyrometry.

HARTFORD—Second Tuesday, with the exception of January 15. H. I. Moore, secy., Firth Sterling Steel Co. Phone, 6-5554 Hartford.

Nov. 13—Technical Solution of Some Practical Problems in the Brass Industry ..... A. J. Phillips
Dec. 11—Cast Iron ..... P. W. Blackwood
Jan. 15—Some Present Trends in Engineering Steels ..... C. E. MacQuigg
Feb. 12—Electric Heat in Industry Motion Picture ..... Lewis Knapp

Mar. 12—Bronze Bearing Metals and Their Heat Treatment ..C. H. Bierbaum
Apr. 9—Globar Heating Elements and Their Application to Heat Treating Furnaces .....Arnold Pfau
May 14—Nitralloy and the Nitriding Process .....V. O. Homerberg
June 11—Tenth Annual Banquet.

INDIANAPOLIS—Second Monday. N. R. Gorsuch, secy., Citizens' Gas Co., Indianapolis.

Oct. 15—Nitralloy .....H. A. DeFries
Nov. 12—Malleable Castings .....H. A. Schwartz
Dec. 10—Steel Failures and How to Produce Them .....H. B. Knowlton
Jan. 14—Fatigue of Metals .....H. F. Moore
Feb. 11—Ask Me Another; Speakers—All Those with a Question or an Answer.
Mar. 11—Manganese Steels .....J. H. Hall
Apr. 8—Indiana Meeting.
May 13—Aircraft Metallurgy .....J. B. Johnson
June 1—Second Annual June Frolic.

MONTREAL—D. G. MacInnes, secy., 377 Claremont Ave., Westmount, Montreal.

Oct. 22—Brass and Some Other Copper Alloys.....W. H. Bassett
Oct. 30—Heat, Rust and Acid Resisting Steels .....W. H. Hatfield
Nov. 19—Rail Steel Manufacture and Specifications.....H. B. Greensted
Dec. 1—Smoker and Entertainment
Jan. 14—Corrosion of Steel .....F. N. Speller
Feb. 11—Manufacture of High Strength Iron .....R. C. Gray
Mar. 11—Modern Developments in Locomotive Forgings .....L. H. Fry
Apr. 8—Centrifugal Pipe in Sand Molds .....J. T. MacKenzie

NEW HAVEN—Third Thursday, with the exception of November 22 and May 23. F. E. Stockwell, secy., Standard Oil Co. of New York. Phone, Beacon 1520, Pioneer 9940.

Oct. 18—Uses and Application of Copper and Copper Alloys....H. W. Staples
Nov. 22—Procedure of Correct Hardening .....Jordan Korp
Dec. 20—Jewels of Industry—Moving Picture.
Jan. 27—Stainless Iron .....N. L. Mochel
Feb. 21—Nickel Chromium Alloys in Gray Iron .....D. M. Houston
Mar. 21—Chromium Plating .....William Blum
Apr. 18—Non-Ferrous Metals .....Arthur Phillips
May 23—Subject to be announced later .....A. Cook
June —Annual Outing.

NOTRE DAME—Second Thursday. C. E. McDermott, secy., 511 E. Howard St., South Bend, Ind.

PITTSBURGH—First Thursday. H. L. Walker, secy., 414 Tripoli, Pittsburgh, North Side Station.

WASHINGTON-BALTIMORE—Third Friday. J. E. Crown, secy., 727 Fifth St., Washington.

October —The Application of Science to the Steel Industry.W. H. Hatfield
November—Aircraft Metallurgy (Baltimore meeting) .....H. C. Knerr
December—The Age of Speed, movie and lecture.....Norton Company
January —Steel Castings .....R. A. Bull
February —Recent Developments in Copper Alloys.....W. H. Bassett
March —Corrosion of Metals .....U. R. Evans
(Three lectures—joint meeting with several other scientific societies in Washington)
April —Metallurgical Applications of Vanadium .....Jerome Strauss
May —Open

WORCESTER—C. G. Johnson, secy., Worcester Polytechnic Institute. Phone, P110.

Oct. 16—Castings .....V. T. Malcolm
Nov. 8—Brass—Speaker to be announced later.
Dec. 13—Ball Bearing Steels .....F. G. Hughes
January Meeting—Mechanical Working of Steel .....A. W. F. Green
February Meeting—Practical Heat Treating Troubles.....W. S. Bidle
March Meeting—Plating of Metals—Speaker to be announced later.
April Meeting—Questions—Speaker to be announced later.
May Meeting—Subject and speaker to be announced later.

STANDING OF THE CHAPTERS

DURING the month of September there were 145 new and reinstated members, while 85 were lost through non-payment of dues and 15 for resignations and deaths, leaving a net gain of 45 members for the month.

The total membership of the society on October 1, 1928, was 4889.

GROUP I		GROUP II		GROUP III	
1. Detroit	478	1. Los Angeles	161	1. New Haven	97
2. Chicago	431	2. Hartford	144	2. Tri-City	85
3. Pittsburgh	363	3. Golden Gate	123	3. Worcester	74
4. New York	321	4. Lehigh Valley	119	3. Washington	74
5. Philadelphia	315	5. Milwaukee	115	4. Rockford	63
6. Cleveland	293	6. St. Louis	104	5. Providence	58
7. Boston	247	6. Cincinnati	104	6. Rochester	57
		7. Dayton	99	7. Toronto	53
		8. Indianapolis	96	8. Southern Tier	50
		9. Canton-Mass.	83	9. Columbus	48
		10. Buffalo	83	10. Schenectady	45
		11. Syracuse	80	11. Springfield	38
		12. Montreal	69	12. Fort Wayne	26
		13. North-West	57	13. Notre Dame	23

GROUP I—All the chapters remain the same as on the report last month. Pittsburgh with a gain of 7 and New York with a gain of 6 had the highest increases for the month.

GROUP II—Los Angeles for the first time in many months has the same number of members as for the preceding month. Hartford with a gain of 5 is rather securely entrenched for the time being in position 2. St. Louis and Cincinnati are still in a tie for sixth place, while Buffalo with a gain of 4 passed Syracuse and advanced from twelfth to eleventh place.

GROUP III—New Haven still heads the group with a lead of 12 members over its closest rival. Tri-City is again active and with a net gain of 12, being the highest of any chapter for the month, advanced from fourth to second place. Worcester and Washington with 74 members each are tied for third place. Toronto with a gain of 1 member passed Southern Tier who having suffered a loss of 3 members now occupies position 8.

BOSTON CHAPTER

The ninth annual banquet and smoker proved to be the most successful one ever held by the Boston Chapter. Departing from custom of the past few years, when the smoker has been preceded by a Saturday afternoon outing at one of the local country clubs, this year it was strictly an evening affair, being held at the University Club, Boston, October 1. That the judgment of the committee was correct, in making the change, was indicated by the presence and enthusiasm of one hundred and twenty members, or approximately one-half of the total chapter enrollment.

Dinner was served at 6:45 in one of the main banquet halls of the club, music and songs being furnished by the "Friendly Maids" or "Dutch

Girls,'' familiar to all radio listeners in this part of the country. Let it be said at this time that the radio does not do justice to these talented young women, each of them a soloist of note. Their songs, dances and musical selections continued throughout the evening.

Eclipsing all of his previous efforts, chairman Harry Parker, chief booking agent of the Boston chapter, proved again that it takes a single man to pick the winners. His selections were all good, as usual. Immediately following the dinner, Earl Downing, of the Lynn G. E. Works, who achieved considerable fame in the International Harvester Company's pickle-house during the Chicago Convention, and who distinguished himself as an umpire at the chapter outing last year, happily assisted ''Marge,'' leader of the ''Dutch Girls,'' in directing the singing. The chapter auditor, A. B. Day, performed an exhibition dance with the same young lady. Apparently these two gentlemen from the great wide open spaces surrounding Boston had met Marge on some former occasion, and at this point, to avoid further complications, the chairman suggested that all of those present resume their seats.

Robert Burlen, announcer for Station WEEI, mouthpiece of the Stetson Shoe Parade and many other familiar broadcasts, told stories and Billie Williams, also from the same station, entertained the gang with her charming personality, etc., and piano-accordion solos. It has been suggested that station WEEI be requested to feature Billie in the evening, rather than during the morning hours, so that the local steel pedlars and treaters could see more of her.

During the evening Dr. Waterhouse described in detail the meetings and visitations to be held this year and the chapter was doubly honored with a few words by its highly esteemed honorary member, Dr. Albert Sauveur of Harvard University. The program was brought to a close with a round of applause to chairman Parker for a most enjoyable evening.

The special committee in charge of arrangements consisted of Dr. G. B. Waterhouse, general chairman; A. D. Bach, banquet and smokes; H. B. Parker, entertainment; E. C. Carlson, reception; and the secretary.

Howard E. Handy.

CHICAGO CHAPTER

Chicago Chapter opened its 1928-1929 season with a bang at a meeting held at the City Club on Thursday evening, Sept. 13, 1928. About 125 were present for the fried chicken dinner, and later arrivals for the evening brought the total attendance figure to almost 200.

During the serving of the early courses of the dinner an old time pep session was inaugurated by the singing of, ''Hail, Hail.'' Other numbers were followed by vocal and piano selections by Miss Beatrice Wood, and James Kozak; and various humorous adventures of a Russian named Mike Casey were narrated by Ned Melroy.

The business of the evening began with a few remarks by our new chairman, A. M. Steever, and the secretary, J. A. Comstock. The technical program for the year, which appears on another page of TRANSACTIONS, was announced by the chairman of the papers committee, W. A. Scheuch. It

is evident that the Chicago Chapter will enjoy some profitable evenings this winter. The chairman then called on our past national president, J. Fletcher Harper, for a few remarks. He responded with his characteristic good humor, and extended invitations to all A. S. S. T. members to visit meetings of other chapters whenever opportunity presented.

The technical session was preceded by a three-reel motion picture, "The Story of Ingot Iron". This picture was produced by the Bureau of Mines in cooperation with the American Rolling Mill Co. and is the first of a series which the Chicago chapter intends to present this season.

The speaker of the evening was R. E. Talley, president of the George J. Hagan Company, of Pittsburgh. He gave an able and well informed talk on "Furnaces"; illustrated by numerous slides showing actual furnace installations and construction details. Mr. Talley had at his tongue's end actual fuel and maintenance costs on these furnaces, determined by months of operation. He covered so many details that few questions were presented when he concluded. The discussion centered around the ever present question of the most desirable fuel, Mr. Talley maintaining that no general rule on which to select fuel can be given. Each installation, he said, should be engineered on its merits, and the fuel selected which would give the most economical results in the long run.

The meeting was closed with a rising vote of thanks to the speaker.

D. L. Colwell.

CLEVELAND CHAPTER

The first regular meeting of Cleveland Chapter A. S. S. T. was held Monday, Sept. 17, 1928, at the plant of the Bourne-Fuller Company, Cleveland.

The activities started at 2:30 P. M. with a trip through the bolt and nut division, followed at 6:30 by dinner in the cafeteria where the members were guests of the Bourne-Fuller Co. Immediately after dinner Chairman D. M. Gurney called the meeting to order and very snappily transacted the business of the evening, calling on Chairman J. H. Cox of the membership committee and Chairman W. T. Donkin of the on-to-Philadelphia committee for their reports.

E. J. Kreps, vice-president of Bourne-Fuller Co., was requested to make a few remarks, and he responded by welcoming the members and guests to their plant. Mr. Hopkins, secretary, Mr. Hartford, general superintendent, Mr. Schartz, Mr. Cain, Mr. McNaughton, Mr. Watkins, and other officials of the company were then introduced to the members.

The meeting was then opened to questions concerning the afternoon trip which were answered by Harry Ellison, superintendent of the nut and bolt plant, and Charles Newpher, sales engineer.

Fred McNaughton gave a description of blast furnace operation, R. L. Cain, the open-hearth, W. H. Watkins, the finishing mill, and H. H. Smith, our fellow member, steel plant inspection.

After a rising vote of thanks to the Bourne-Fuller Co. for their splendid hospitality the meeting was adjourned and the inspection of the steel plant followed where the blast furnace, open hearth and finishing mills were visited.

This meeting was one of the most popular ever held by the Cleveland Chapter, 180 members and guests turning out for the occasion.

J. S. Ayling.

DAYTON CHAPTER

The first meeting of the 1928-1929 season of the Dayton Chapter was held Monday evening, Sept. 17. Thirty-five members assembled for dinner at the Engineer's Club. For an hour immediately following the dinner Lt. S. P. Mills, of Wright Field, talked on "Aviation in the Philippines". Lt. Mills who just recently returned to Wright Field after two years' foreign duty spoke entertainingly of life and customs in this group of islands. Illustrated by a large number of colored slides, Lt. Mills gave his audience a clear understanding of the geography of the islands, the racial characteristics of the people and showed how they live; their houses, their religious customs and beliefs and their industries and agricultural pursuits.

The principal speaker of the evening was A. H. D'Arcambal, consulting metallurgist for the Pratt and Whitney Co. of Hartford Conn., who discussed "Small Tools and Gages". Mr. D'Arcambal's talk was wholly practical and very instructive, not only to the tool makers present but also to our heat treaters and technical members. The first point stressed was the importance of proper design for small tools. Design is as important or even more important than any other factor in the life of tools.

Next to design the most important factor in the life and performance of tools is the quality of the steel. The speaker outlined the specifications under which tool steel should be purchased and showed how in his own experience, rigid metallurgical control in purchasing reduced rejections and improved quality of the finished tools. Following this Mr. D'Arcambal discussed the various grades of tool steel and their use for different kinds of tools. This discussion included plain carbon tool steel, carbon-vanadium tool steel used particularly for small taps, and a comparison of water and oil hardening tool steel in which the speaker stated his preference for water hardening steel except when size change in heat treatment is to be avoided.

High speed steel was taken up in detail. Carbon is the most important element and the percentage must be held to close limits, next to carbon is vanadium. The close control of the chromium and tungsten is not so essential. Some of the newer cobalt high speed steels are proving to be excellent material for lathe tools and the like. They harden with a soft skin, consequently their use is restricted to tools than can be ground all over.

Following the discussion of the composition of the steel, Mr. D'Arcambal took up the heat treatment of small tools, and described the electrical lead pots and oil tempering baths used by his company. He had curves showing the relation between quenching and tempering temperatures and the life and performance of high speed steel. These curves proved conclusively that high speed steel must be quenched from temperatures exceeding 2300 degrees Fahr. and must be tempered between 1050 and 1200 degrees Fahr. to give best results. A quenching temperature of 2330 to 2350 is used for most high speed tools.

The lecture was illustrated by slides and was accompanied by a fine

exhibit of small tools and gages. Among the tools were specimens which had failed prematurely or had been rejected for various defects, and also many specimens which had seen exceptional service. The discussion lasted until nearly midnight.

The regular monthly meeting of the Dayton Chapter was held Monday evening, October 15, at the Engineer's Club. Thirty-five members gathered for a chicken dinner at 6:30 P. M. Following the dinner, A. C. Jackson, vice president of the Dayton Savings and Trust Co. gave a 45 minute talk on "The Banker and the Engineer." In language understood by every steel man present, Mr. Jackson discussed the relation of the banker and the engineer, and told how each was dependent on the other. It was necessary, he said, for the banker to take an active interest in engineering and its projects in order to intelligently serve and finance the engineering industries.

It was also necessary for the engineer to understand the fundamental principles involved in applying for a loan regardless of whether this loan was personal or for his company. Mr. Jackson concluded by describing and explaining the balance sheet, the statement of operating schedules, accounts receivable, payrolls, bad debts and reserves which are required by the bank as preliminary to granting a loan.

Following the dinner talk, Fred M. Reiter, secretary of the Dayton Chapter and delegate to the convention, described the Philadelphia meetings and exposition. About 20 members of our chapter were in attendance at the convention.

The speaker of the evening was F. R. Bonte, metallurgist of the Union Drawn Steel Co., Beaver Falls, Pa. Mr. Bonte's subject was "Cold Finished Steels." Before an audience of fifty members the speaker described the development of the cold-drawn steel industry and the applications of cold-drawn steel. Profusely illustrated by lantern slides, the lecture began with the manufacturing processes in cold-drawing steel and included a complete description of the properties and structure of the various grades of cold-drawn and cold-rolled products. Machinability was discussed in detail in its relation to chemical composition, structure and surface. Mr. Bonte took up the various grades of steel now being furnished in the cold-drawn condition, from the common Bessemer screw stock to some of the chromium-nickel and chromium-vanadium alloy steels and described and illustrated the effect of cold-drawing of their properties and structure.

In concluding the lecture the speaker described and showed numerous slides of industrial application of unusual cold-drawn shapes to the printing press, the cash register, the filing cabinet and miscellaneous office supplies and many others. At present there is an increasing demand for special cold-drawn shapes to supplant expensive machined sections. The discussion which followed the lecture lasted until a late hour. *F. T. Sisco.*

GOLDEN GATE CHAPTER

The September meeting of Golden Gate Chapter was held on the evening

of September 19 at the Engineers' Club, San Francisco. Dinner was served at 6:45.

The meeting was called to order by Dr. W. J. Crook, chairman, and regular business was first taken up. Reports of the various committees were read.

A special report was given by E. E. Fess, chairman of the educational committee. This committee is proceeding with plans for a continuation of the preliminary course in heat treating somewhat as given previously, and in addition an advanced course covering the practical applications of heat treating and metallurgical subjects taken up. The progress made in these plans is due to the generous stand taken by our sustaining members, and to the cooperation given by the Humboldt Evening High School of San Francisco. The tentative plans for the two courses, requirements for attendance, and so forth, were thoroughly discussed, and several entrance applications were received.

Short discussions upon "Iron and Carbon," and "Annealing and Normalizing," were led by Messrs. Thurston and Coulter respectively.

The main talk of the evening was given by George A. Nelson, of the Shaw Laboratory, upon the "Optics of the Metallurgical Microscope and Its Applications to Bearing Metals." Mr. Nelson demonstrated his points by diagrams and illustrations, and submitted many illustrations of the structures of the different types of bearing metals. The care necessary in the preparation and etching of sections of this type were carefully explained, as was also the effect of each type of structure upon the physical properties of the bearing. This talk was much appreciated, and brought out considerable discussion.

H. E. Morse.

HARTFORD CHAPTER

On Sept. 11, the first meeting of the season 1928-29 was called to order at 8:15 P. M. by our new chairman John C. Kielman. After calling our attention to the excellent program of meetings for this season, he introduced the speaker of the evening, Henry E. Allen, chief metallurgist of Henry Disston and Sons, Philadelphia. Mr. Allen is well qualified to talk about his subject which was "Tool Steels". In the course of his talk he outlined the several classes of tool steels and their particular applications.

The effect of the various alloys was dwelt upon at some length, showing the different properties the different elements impart. A particular alloy tool steel of nickel and molybdenum with about 0.85 per cent carbon was described as capable of hardening through a section of 1.25 inch when water quenched. This is a case of a combination of alloys producing a great "hardening effect" while either of the alloys alone in the same amount would not produce the same depth of hardness.

The addition of molybdenum to chromium steels produced a finer grain and makes tougher tools. The application of high speed steel tools to wood working machinery and a high carbon, silicon, manganese steel for finish turning chilled iron rolls were some of the applications Mr. Allen talked about.

A rising vote of thanks was given Mr. Allen for his instructive talk and the discussions which followed were from several members interested in special applications of the various types of steel.

All meetings for the year 1928-1929, which are listed elsewhere, will be held in the Hartford Electric Light Co. Auditorium with the exception of the banquet.

This is an interesting program and vice chairman Edson L. Wood is to be congratulated in securing these men, several of whom are eminent authorities. Dr. Hatfield has devoted many years to a special study of stainless and heat resistant steels and this year delivered the Edward De Mille Campbell Memorial lecture at the National Convention at Philadelphia. P. W. Blackwood has had a wide foundry experience in the middle west automotive field. Mr. Bierbaum is an authority on bronze and will be the first speaker to present this subject to the Hartford Chapter. Professor Homerberg has done considerable research work on the nitriding process.

Henry B. Smith.

The October meeting of the Hartford Chapter was held on the second, a week earlier than the regular schedule. A large attendance was on hand to hear Dr. W. H. Hatfield, director of the Brown Firth Research Laboratories at Sheffield, England, and also the Campbell Memorial Lecturer at the National Convention. He addressed his first American audience on this evening in the Hartford Chapter, his subject being: "Acid, Corrosion and Heat Resistant Steels." He developed his subject by showing numerous slides which exhibited a vast amount of experimental work in corrosion upon different steels.

To begin with he held that the thin oxide film only a few molecules thick was responsible for resistance to corrosion. He cited Ulick Evans' clever experiment in separating the iron from the oxide film leaving the film floating about in solution like the finest gossamer, assuredly showing under the microscope the film in a tangible manner. In another experiment Dr. Hatfield showed that a steel plate, not of stainless steel but of common mild steel, when polished and exposed to the weather but protected by a gauze in front of the polished face remained bright and uncorroded for many months. He explained this "phenomenon" by reasoning that the oxide film on ordinary steel was very liable to mechanical injury. Protection from all particles of dust and dirt insured that no injury to the film took place and, therefore, no nucleus for corrosion was available. The oxide film on high-chromium and high-chromium-nickel steels is very tenacious and mechanically strong. Dr. Hatfield showed in a tabular way the results of corrosion tests performed under standard conditions on a series of steels with varying chromium content; on another series of chromium-nickel steels with the nickel content constant; and another series with the nickel varying and chromium constant. A great advantage in general corrosion properties is gained by adding nickel to chromium steels, the 18 per cent chromium, 8 per cent nickel proving an excellent type for general corrosion properties. For any specific case in acid resistant applications a certain steel can be found to "do the job." Stainless steel for resisting corrosion of superheated steam at 1000 degrees Fahr. is applied in turbine blading and valve parts. A chromium-nickel-silicon steel is useful in applications where a high tensile strength is necessary at an elevated temperature, such as 700

to 800 degrees Cent. At this temperature it has the strength of mild steel at room temperature, and the non-scaling properties of this steel are excellent. *Henry B. Smith.*

INDIANAPOLIS CHAPTER

The first regular meeting of the Indianapolis Chapter was held the evening of Sept. 10 in the main dining room of the Chamber of Commerce Building. There were fifty members and guests assembled. Dinner was served at 6:30 o'clock.

Mr. Fisher, chairman, called the meeting to order at 7:30 o'clock, and after making the members acquainted with the new officers and new members that have come with us during the summer, introduced Claude S. Gordon of the Claude S. Gordon Co. of Chicago, who was our speaker and guest of the evening.

Mr. Gordon's subject was "Pyrometry", and was most ably presented with illustrated picture slides. He took us from the period when old man goggle eyes was the determining factor as to the temperature being maintained in a heat treating furnace to the present time when all human element has been eliminated with automatic recording and control instruments. Those who heard Mr. Gordon were well repaid for attending on an evening as warm as Monday night. *N. R. Gorsuch.*

LEHIGH VALLEY CHAPTER

The first meeting of the season was held at the Elk's Home in Phillipsburg, N. J., on Friday, Sept. 7. A very successful meeting it was, the attendance being in excess of the membership, all sections of the chapter being well represented, the Reading delegation being almost 100 per cent strong.

Chairman Walter L. Trumbauer gave the members an idea of the plans for this year by reading the minutes of the first executive committee meeting, these minutes contained a schedule of the meetings for the year 1928 and 1929.

At this committee meeting it was decided to adopt a set date for our meeting nights, the first Friday of each month, in the hope that this night would always be reserved and looked forward to as A. S. S. T. night.

We can thank ourselves for the success of this first meeting, as we used foresight in selecting a speaker of the caliber of J. A. Doyle. Mr. Doyle, the vice-president of the W. S. Rockwell Company, of New York City, is a drawing card at any time, but when he titles his subject "Heat Treating Bunk" he is doubly so.

The bunk was divided in three parts, namely, technical bunk, practical bunk and the remedy for said bunk.

Under the first heading, the subject of treatment literature, particularly text books, was discussed. They contain plenty of theory, which is alright only when coupled with the common sense principles of practical treatment, the latter usually being conspicuous by their absence.

The misuse of furnaces was the first item considered under practical bunk. Mr. Doyle stressed the point that automatic continuous furnaces

are only applicable where the quantity of work is such as to warrant a furnace designed for one job and one job alone, such being the case in the the automobile industry. In 99 per cent of all other cases a semi-automatic furnace is preferred. As to the operation of furnaces he included the subjects of burners, fuels and fuel economy; stating that the claims of higher efficiencies and higher fuel economies from different types of fuels and burners were 100 per cent bunk. In his opinion every type of fuel has its own field, dependent mainly on the cost of that fuel at the particular plant. Combination preheating and treating furnaces as well as recuperators are alright if the thought is kept in mind that the prime motive is to treat the work properly and not just to save fuel.

Due to the keen competition in industry today it is necessary to constantly have cheaper and better treatment. This can be accomplished by having better men and better equipment. However, it is Mr. Doyle's opinion that the man behind the furnace counts for 75 per cent and the equipment 25 per cent. He suggests that high class men be used as treaters in as much as the quality of work is so highly dependent on them. These men can be attracted only by improving the working conditions about the furnaces and by paying them higher wages. He feels sure that this is the answer to cheaper and better heat treatment.

A lively discussion followed Mr. Doyle's talk, after which the meeting adjourned.

John K. Killmer.

LOS ANGELES CHAPTER

Dinner started promptly at 6:30. Seventy-three members and visitors were at the tables, and about twenty came in after dinner. The dinner was good, plenty of it. The Morris Sisters of Ira Gay entertained with songs and dancing during dinner.

After the introduction of the visitors by chairman Hampton, the trophies for the Ventura golf match were distributed to the winners with appropriate remarks regarding their perfect golf. The winners were:

Low gross—Curly Wilkinson, L. A. Rubber Stamp Co.
First bogey—Harold Howard, Ducommun Corp.
Second bogey—S. E. Tiber, Ducommun Corp.
Highest possible—Fred Arnold, Doheny Stone Drill Co.

Considerable enjoyment was had razzing the winners, especially so when Fred Arnold received the granite ware catcher. Photos of the winners, with their cups, and of the whole dinner group, were taken.

Chapter business was then taken up. Three chapter members, Wm. Ely Nelson, Ray Catland and Bill Laurey, intend to visit the annual convention at Philadelphia. Ray Catland was elected to represent the Los Angeles Chapter, with Wm. Nelson as alternate. Chairman Hampton appointed Morris Pendleton to arrange with the Chamber of Commerce to furnish suitable souvenirs for the Los Angeles delegates.

Carl Fromme made a report on the progress of his work, which showed a satisfactory condition at this season.

Bill Laury's report on the arrangements for the programs for the Los Angeles Convention was read. A fine program has been arranged covering the field of heat treatment.

Chairman Hampton reviewed the Ventura picnic, and a big vote of thanks was given to Ralph Hall.

Unfortunately, Jim Spade was called East and the chapter was deprived of a fine talk on an interesting subject. The five reel Bureau of Mines picture on iron filled the balance of the evening very well, and the meeting adjourned with a feeling that everyone had his money's worth.

H. V. Ruth.

MILWAUKEE CHAPTER

The first fall meeting of the Milwaukee Chapter was held as a social meeting at the Miller Garden on Monday, October 1. Before the meeting a steak dinner was served which was favorably commented on by the members present.

The meeting opened with a short address by the chairman, M. G. Jewett, covering the plans and arrangements for the coming year to increase the membership and also increase the usefulness of the society to its members. This talk was followed by an invitation to members to discuss the subjects mentioned, which brought out considerable interesting discussion.

The coming convention at Philadelphia was also discussed, and all members were urged to attend if in any way possible. A special train will be run from Chicago by way of Detroit and Niagara Falls, and all members who wish to do so were asked to take advantage of this train and enjoy the society of their fellow members.

The meeting then turned into an informal social meeting and two bowling teams promptly formed, one captained by R. J. Thurner and the other by Charles Engel. They had a very close game, Thurner's five claiming the honors with a score of 662 to 661. A return match was then played which resulted in reversing the honors with not nearly as close a score.

The meeting then adjourned.

L. J. Radermacher.

NEW HAVEN CHAPTER

The first meeting of the season of the New Haven Chapter was ushered in by an informal dinner held at the Bull Dog Grill. Eighteen members sat down and enjoyed a very fine meal which was evidenced by the number of belts which were shyly loosened during the course of the dinner.

The regular meeting was called to order at 8 P. M. by Chairman Harold Fish at the Hammond Laboratory. There were forty-two members present and the officers of the chapter were very gratified at this splendid turnout.

There seems to be a renewed spirit and we are looking forward to a very successful and eventful season.

Although the speaker, Mr. Newton, president of the Newton Die Casting Co., of New Haven, was a little tardy in arriving, his talk was very inspiring and certainly was worth while waiting for. Mr. Newton explained their methods of die casting by forcing the hot metal into the water cooled

dies with an air pressure of 400 pounds. During the course of his talk many die cast articles were passed around and examined.

The various types of steels for the dies were explained, some of these steels being straight carbon, chromium-vanadium, high manganese and high silicon and tungsten, the Brinell hardness of the alloy steel dies running between 380 and 425.

Mr. Newton called attention to the fact that on page 119 of the A. S. S. T. handbook on the recommended practice for the heat treatment of dies for die casting, they state that castings cannot be considered die casting jobs in lots less than 10,000. The speaker's view of this is that they can be considered practical in lots as low as 2,000 to 3,000.

A very lively discussion followed the talk in which many of our members took part.

By the way, we were very glad to have Henry Moore, secretary and treasurer of the Hartford Chapter, with us. Come again, Henry, your smiling face is always welcome.

The Waterbury Farrel Foundry was represented by a delegation of four. As usual two attendance prizes were given; a kitchen clock, donated by Tom Chamberlin, was won by Paul Eddy of the Geometric Tool Co., and a silver bread plate, donated by Walter G. Aurand, was won by R. E. Walsh of the Waterbury Farrel Foundry and Machine Co.

Well, fellows, the next meeting will be held in Bridgeport on Oct. 18. As yet the plant visit has not been arranged, but one thing has; that is where the dinner is to be held. If you remember the feed we had at the Heppenstall Forge Company's plant last year, you will surely be on deck. Carl Sauer promises it to be even better than before. So on to Bridgeport.

R. T. Porter.

PITTSBURGH CHAPTER

The Pittsburgh Chapter held its regular meeting on the evening of Sept. 6 in the U. S. Bureau of Mines Building.

Jerome Strauss, who is now chief research engineer of the Vanadium Corp. of America and formerly was assistant chief chemist and metallurgist at the U. S. Naval Gun Factory at Washington, was the speaker at this meeting.

Mr. Strauss's subject was, "Aluminum-Bronze" and, after his introduction, Mr. Strauss gave a very complete history of his subject, beginning with its composition and possible alloying additions and following it through its melting, casting, forging, heat treatments and applications.

In most cases he had lantern slides which illustrated his diagrams and microstructures.

This talk was one of the best on a nonferrous subject that it has been the pleasure of the Pittsburgh Chapter to hear and the chapter's appreciation was extended to Mr. Strauss at the close of his talk.

Many friends of H. C. Ihsen of the Westinghouse Electric & Mfg. Co., will be interested to know that, with his brother, he hiked from the base to the top of Mt. Rainier while in the Northwest this summer.

Harry A. Neeb, Jr.

PROVIDENCE CHAPTER

The October 3 meeting of the Providence Chapter was held in the Auditorium of the Jesse Metcalf Laboratory at Brown University in conjunction with the Providence Engineering Society.

Our newly elected chairman, E. J. Sullivan, presided, and, after making one or two announcements, turned the meeting over to the speaker of the evening, Dr. W. H. Hatfield, director, Brown-Firth Research Laboratories, Sheffield, England.

The speaker spoke a few words in general on his memorial lecture to be given before the Steel Treaters at the National Convention.

One of the reasons given to show why the Stainless Irons and Steels are just being developed was that the method of attack was all wrong. Dr. Hatfield proved this statement by showing numerous slides giving ratios of solubility of the pure metals (iron, nickel, chromium) and the rustless iron and steels in the three major acids, i. e.; sulphuric, nitric and hydrochloric at different temperatures and concentrations.

Chromium is a material that forms an oxide film rendering the iron passive to further oxidation. That this is true, Dr. Hatfield proved by stating he had seen this film after the inner iron had all been dissolved out. The stainlessness of iron is due to this protective film.

Slides were shown giving the physical and mechanical properties of the corrosion-resisting steels. Some of the applications of the steels were shown by means of slides,—namely, automobile bright work, air service, chemical ware, artistic shop fronts and art work.

The addition of silicon and tungsten gives remarkable scale-resisting properties and increases the tensile strength. Dr. Hatfield concluded by showing slides on atmospheric tests: steam at 540 degrees Cent., and the influence of gases at 900 degrees Cent.

The meeting was very well attended and an unusually interesting discussion followed. The speaker covered this lengthy subject in a very plain everyday manner and was given a unanimous rising vote of thanks.

E. G. Peterson.

ROCKFORD CHAPTER

The first meeting of the season was held Friday, Sept. 14, in the Venetian Room at the Nelson Hotel. About thirty members and guests attended the 7 o'clock dinner, which preceded the meeting.

Chairman R. M. Smith opened the business meeting at 8:00 P. M. and the minutes of the previous meeting were read and approved.

Due to a tornado which struck Rockford shortly after 3:00 P. M. that day there was a very small attendance as it struck the south-east end where most of our large factories are located.

Chairman Smith explained several points about the coming Convention and circulars were passed to members giving railroad schedule, rate, etc., to Philadelphia on a special train from Chicago.

The speaker of the evening was T. E. Talley, president of the George J. Hagan Company, of Pittsburgh, who spoke on "Newer Development in

Furnace Design''. This talk was amply illustrated with lantern slides. Mr. Talley gave a very interesting talk dealing mostly with the externals of furnaces. Many labor saving devices were shown on furnaces for almost any kind of work, and of every size and description.

The meeting adjourned at 10:15 P. M. with a rising vote of thanks to the speaker.

Geo. R. Monks.

ST. LOUIS CHAPTER

The regular meeting of the St. Louis Chapter was held Friday evening, Sept. 21, at the American Annex Hotel.

The meeting was preceded by the usual excellent dinner after which the meeting was called to order by the secretary and treasurer, the vice chairman being absent and our chairman, who had resigned for the reason that he was no longer located in St. Louis. We take this occasion to wish our former chairman, Walter Remmers, all the best success in the world in his new position with the Western Electric Co. at Chicago.

The secretary passed up all laws, rules and regulations and drafted William D. Thompson, who was chairman last year, to fill the chair for the coming year. The meeting was turned over to the chairman at this time who introduced the representative of the Carborundum Co., Calvin M. Christy, who presented the ''Story of Carborundum Refractories'' in four reels of motion pictures. Appropriate souvenirs were distributed at this time. The picture was well received by the attendance, which numbered some 125 members and guests. The special attraction for the evening was the picnic and barbecue picture of our first annual frolic. The boys all saw themselves as we understand the majority do not want their wives to see them. There was no doubt that this was one of the nicest programs that ever happened in the St. Louis Chapter. To see these technical men going back to their boyhood days was indeed a treat and from the many comments heard in the crowd from seeing themselves in motion, I think will make the second annual affair better than ever. Both pictures aroused considerable discussion after which the meeting was adjourned until the next regular meeting.

Carl G. Werscheid.

TRI-CITY CHAPTER

On September 20 the Tri-City Chapter held its regular meeting at the tractor plant of the International Harvester Co. The Moline Dispatch reported this meeting in part as follows:

''That crowd numbered just about all the steel treaters they have in this community, and most of their assistants. It included mechanical engineers, chemical engineers, industrial engineers, and just plain engineers and mechanics.

''And it included the score or so of professors who make up the faculty of the school of engineering of the State University of Iowa, and a dozen students from that school.

''It included a dozen or more men from the industries of Kewanee. And it included one or two men who probably had never seen the insides of a factory.

"These engineers, mechanics and what not ate and sang, aided by the pretty office girls of International who officiated as waitresses, by Al Fensterbush, who works at the tractor plant by day and sings by night, by Al Douglass, former Moline alderman who is one of the hardworking executives of the tractor plant, by George Uhlmeyer, industrial engineer of the People's Power Company and chairman of the steel treaters, by McGee and Owen of the tractor works, by J. W. Philips, tractor plant superintendent, and by quite a few others.

"Then they took that marvelous sight-seeing trip through that mammoth industrial institution which the International Harvester Company has developed here in the last two years.

"They walked the two long blocks of the assembly line, where the various parts of the tractors are put together—to the number now of 125 a day."

George A. Uhlmeyer.

WORCESTER CHAPTER

The first meeting of the new season was held at Rebboli's restaurant on Thursday, Sept. 13. Mr. Bigelow, chairman, made several announcements concerning coming local meetings of the A. S. S. T., the national convention in Philadelphia, and progress of the Worcester Engineering Society. The membership of the local chapter also showed a favorable increase during the summer months. Mr. Bigelow then introduced the speaker of the evening to about 70 members and guests.

H. A. DeFries, consulting metallurgist of the Ludlum Steel Co., Watervliet, N. Y., spoke on recent developments in the metallurgical field with particular reference to the development of new ferrous alloys in France and Germany. Mr. DeFries noted three developments which are listed in the order of their importance: I. Manufacture of stainless steel and iron products; II. Tungsten carbide, and III. Nitralloy and aluminum steels. The first two have been developed to a far greater degree in Europe than in the U. S. but the third item, although it has been adapted to a few specific cases in France, is being used for varied articles of commercial importance in this country, exceeding European development.

I. Outstanding in the development of stainless iron and steel has been the research to determine physical constants and temperature effects up to 1800 degrees Fahr. of various alloys of carbon, chromium and nickel and the discovery of satisfactory heat treatments to permit deep drawing of sheet and the drawing of fine wire. Practically all patents have been pooled permitting research by various companies without danger of infringement.

II. Tungsten carbide has hardness greater than nitralloy and nearly equal to the diamond. It is formed while in a plastic condition and brazed onto steel base for support. In its finished form, machining can be accomplished only by a certain type of emery wheel running at very high speed.

III. Nitralloy is being used in France for a few specific uses principally in locomotive guides and airplane engines but is being used in this country for a great many parts where wear is important. The important point in using nitralloy is never to use two nitralloy surfaces in contact with each other.

R. C. Jordan.

Items of Interest

LEIGH M. GRIFFITH, formerly development engineer for the Paramount Famous Lasky Corp., is now vice-president and general manager of the Emsco Aero Engine Co., Los Angeles. Mr. Griffith will be chiefly interested in the development and manufacture of lightweight diesel engines suitable for aircraft and similar duty.

H. G. Freeland, formerly with the Federal Bearings Co., is now in charge of the sale of steel in the state of Connecticut for the Atlas Steel Corp., Dunkirk, N. Y.

The Electric Steel Founders' Research Group has issued a booklet entitled, "Competitors Who Have Cooperated." This booklet contains not only information regarding the organization but reference matter concerning the product of the steel casting industry. The features of the competitive work of this group are described. Copies of this booklet may be obtained by addressing a request to Electric Steel Founders' Research Group, 541 Diversey Parkway, Chicago.

The International Nickel Co., 67 Wall St., New York, has available for distribution a 12-page leaflet entitled, "Wasp and Hornet Aircraft Engines and Their Use of Nickel Steels." This includes a discussion of the materials used in their construction. General specifications of both engines are given, with power and fuel consumption charts and photographs of numerous typical installations in military, naval and commercial service.

The Poldi Steel Corp. of America, 245 W. 18 St., New York, has available for distribution current stock list D 28, also a chart containing general remarks on the hardening of steel and fundamental rules for the correct hardening of tools.

The American Manganese Steel Co., 333 N. Michigan Ave., Chicago, has issued a pamphlet describing the history of the development of "Amsco" manganese steel. This also includes a list of its uses in various industries.

"Practical Industrial Furnace Design" is the title of a book by Matthew H. Mawhinney recently published by John Wiley and Sons. The text is composed of nine chapters which are headed as follows: Introduction, Selection of Fuels, Application of Heat and Furnace Capacity, Methods of Material Handling, Fuel Consumption and Heat Saving, Refractory Design and Construction, Design of Metal Parts and Auxiliaries, Temperature Measurement and Furnace Control, Practical Problems in Furnace Design. This book is 6 by 9 inches and contains 318 pages. The price is $4.00 and may be obtained through the Society at 7016 Euclid Ave., Cleveland.

More than a hundred speakers representing twelve countries are tentatively listed to present papers at the Second International Conference on Bituminous Coal to be held under the auspices of the Carnegie Institute of Technology in Pittsburgh, November 19 to 24, 1928, according to a preliminary program announced by President Thomas S. Baker.

According to the plans, ten major subjects are listed for discussion in addition to the addresses of a general nature to be presented by Lord Melchett (Sir Alfred Mond), the British capitalist, Georges Claude, the eminent French scientist, Professor Fritz Hofmann, the German scientist who makes synthetic rubber from coal, Dr. F. zur Nedden, of Germany, F. G. Tryon of the U. S. Bureau of Mines, and others.

Major subjects to be discussed, it is expected, will include "Pulverized Fuel", "Gas Production", "Liquefaction and Hydrogenation", "Fertilizers", "Origin, Composition and Classification of Coal", "High Temperature Carbonization", "Combustion in Furnaces", "Purification and Cleaning", "Tars and Oils", and "Low Temperature Processes."

As indicated in the list of major topics, the chief purpose of the coming conference will be to present the results of recent studies of coal that have to do with improved methods of utilization and combustion. The list of speakers includes the world's leading authorities on the latest developments in improved utilization of coal as a source of energy and power.

Germany will apparently be represented by the largest delegation with about twenty of her most distinguished scientists and engineers in attendance. France, England, and Canada will also be represented by comparatively large numbers of scientists who have been identified with the latest discoveries in coal research. Other countries that will be represented on the program of speakers are Russia, Italy, Japan, Austria, Denmark, Belgium, and Jugo-Slavia. In addition, delegates have been appointed to represent governments and scientific organizations in Chile, Cuba, Czecho-Slovakia, Norway, Poland, Roumania, and Spain.

Approximately sixty of the 103 speakers already listed to participate in the proceedings, the announcement points out, will come from outside of the United States.

An investigation of blast furnace operation, conducted by the United States Bureau of Mines at its Pittsburgh Experiment Station, has shown that irregular operation of the blast furnace results in increased silicate content of the pig iron. The results of this test show that if the blast furnace was running evenly the silicates in the pig iron were always low, whether the silicon content of the pig iron was 0.6 to 0.7 or 1.30 to 1.40 per cent. However, when an irregularity occurred in furnace operation, causing the silicon to change from one level to another—i. e., from 1.10 to 0.8 per cent—the silicates in the iron were immediately increased. During the test period the silicon content of the iron changed definitely six times, and with each change in silicon there was a pronounced rise in silicates in the iron. This indicates that changes in temperature in the furnace cause an uneven flow of stock into the hearth and bring about a condition where

(Continued on Page 36 Adv. Sec.)

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the iron silicates are fed into the hearth faster than they are reduced. On this particular test the open-hearth heats were all low-carbon heats and the silicates in the iron did not affect the finished product. However, it is known from other work that if the pig iron contains very large percentages of silicates the finished steel will show high percentages of silicates, and it is felt that the results of this test are the first step toward the solution of the problem of pig iron quality and its effect on the finished steel.

By a process of vacuum distillation, pure manganese is now being produced in the Bureau of Metallurgical Research of the Carnegie Institute of Technology, it is announced. Successful purification of the metal by the distillation process, it is pointed out, has been achieved as the result of research by Dr. F. M. Walters, Jr., director, and Drs. V. N. Krivobok and J. B. Friauf, associates of the Bureau.

The purified manganese, the Carnegie Metallurgists say, will be used in a comprehensive study of the system, iron-manganese-carbon. Although manganese is widely used in the steel industry, it has never been prepared in a pure form in any great quantity. The ordinary processes of reduction of manganese from its ores yield a product which is contaminated by several per cent of impurities, and the electrolytic method of refining which is so successful in the treatment of many metals is less readily applicable to the purification of manganese.

Metals of low melting point such as mercury, cadmium and zinc, it is pointed out have been purified by distillation. The method of distillation developed by Dr. Walters and his associates at Carnegie is considered as significant because of the high melting, 1244 degrees Cent., of manganese.

The process used at the Bureau of Metallurgical Research is described as follows: Crude metallic manganese is placed in a pure magnesia crucible over which a similar crucible is inverted to condense the distilled metal. The crucibles are placed inside a silica tube four inches in diameter and two feet long which is closed at both ends and connected to a vacuum pump. The central portion of the silica tube is surrounded by a water cooled copper coil of about thirty turns, through which an alternating current of several amperes at a frequency of some twenty kilocycles is passed. This induces eddy currents in the manganese and heats it to the melting point. The pressure maintained in the silica tube by the vacuum pump is less than a twenty-thousandth of the atmospheric pressure. The molten manganese boils under the low pressure and sends off manganese vapor which is condensed in the upper crucible. The impurities remain in the manganese in the lower crucible, while the distilled metal which has been formed by the condensation of manganese vapor is of a high degree of purity.

The distilled manganese has a bright silvery luster which does not tarnish upon exposure to air. Unlike many pure metals which are comparatively soft and ductile, distilled manganese is extremely brittle and hard enough to scratch glass.

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